

BBC

SHOULD WE WORRY ABOUT **ASTEROIDS?**

# FOCUS

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**2017  
TECH  
PREVIEW**

THE GOOD,  
THE BAD, AND THE  
OUTRIGHT CRAZY

THE  
VIRUSES  
THAT  
MADE US  
HUMAN

# LIFE AFTER MAN

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At the heart of the image



# WELCOME



Our days are numbered. Between superbugs and supervolcanoes, asteroids and artificial intelligence, the outlook isn't good if you're human. In fact, the future isn't hopeful for most of the planet's inhabitants. We're in the throes of Earth's sixth mass extinction event: the rate of species loss is 100 times larger than expected.

It seems *almost* inevitable (there's always hope!) that, like the dinosaurs before us, we won't be a permanent fixture on Earth. But what will happen after we're gone? How long will it take the planet to recover from the human condition? Find out what's in store for Earth after humankind has disappeared on p38.

Speaking of world-ending events, four years ago this month the Chelyabinsk meteor tore through Russian skies, exploding some 30km above the ground. The meteor's arrival was a total surprise, not least to the 1,500 people injured by the blast. No one had seen it coming. So what are we, as a planet, doing to see off asteroid impacts? Find out on p60.

Here in the present, CES – the world's biggest technology and gadget showcase in Las Vegas – has just come to a close. And one clear piece of news emerged from the hustle and bustle of Sin City: autonomous cars are nearly here. Read our report on p26, and check out our reporting from the show on Twitter @sciencefocus and on our website.

*Daniel Bennett*

Daniel Bennett, Editor

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### KAT ARNEY

Kat Arney has a PhD in developmental biology, making her the perfect expert to investigate the viruses that have shaped our evolution. → p48



### RITA CARTER

Every week there is some new gadget or supplement that promises to make you smarter. Brain expert Rita uncovers the methods that really work. → p54



### DUNCAN GEERE

Experts are sure that we'll go extinct. Science writer Duncan reveals how Earth will cope without us, and takes a look at the legacy we'll leave behind. → p38

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### Life after man

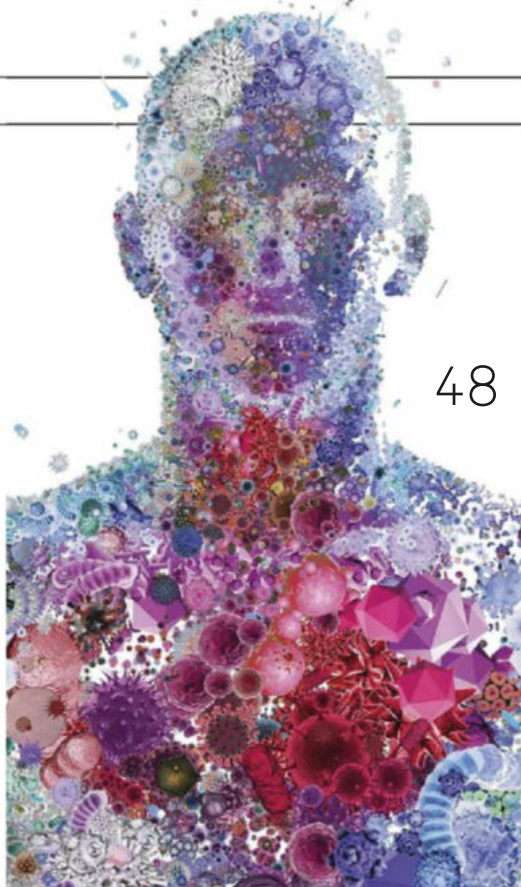
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### The viruses that made us human

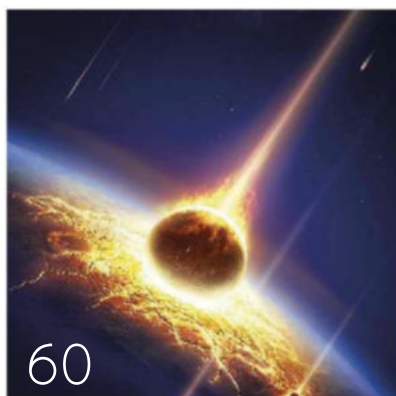
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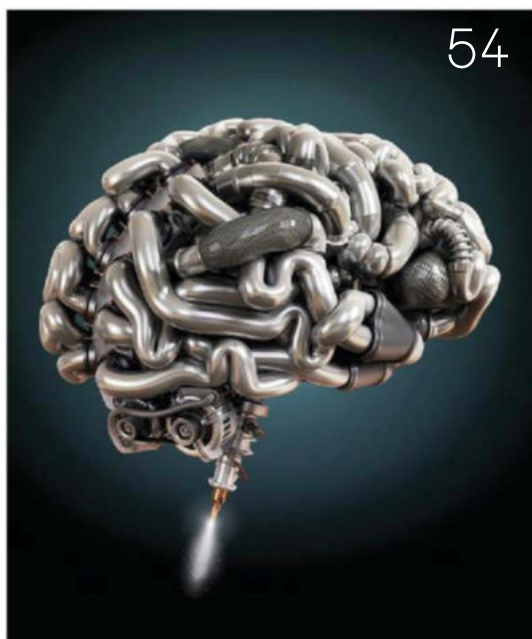
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## WE ARE...

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EYE OPENER

# Monster mech

SEOUL,  
SOUTH KOREA

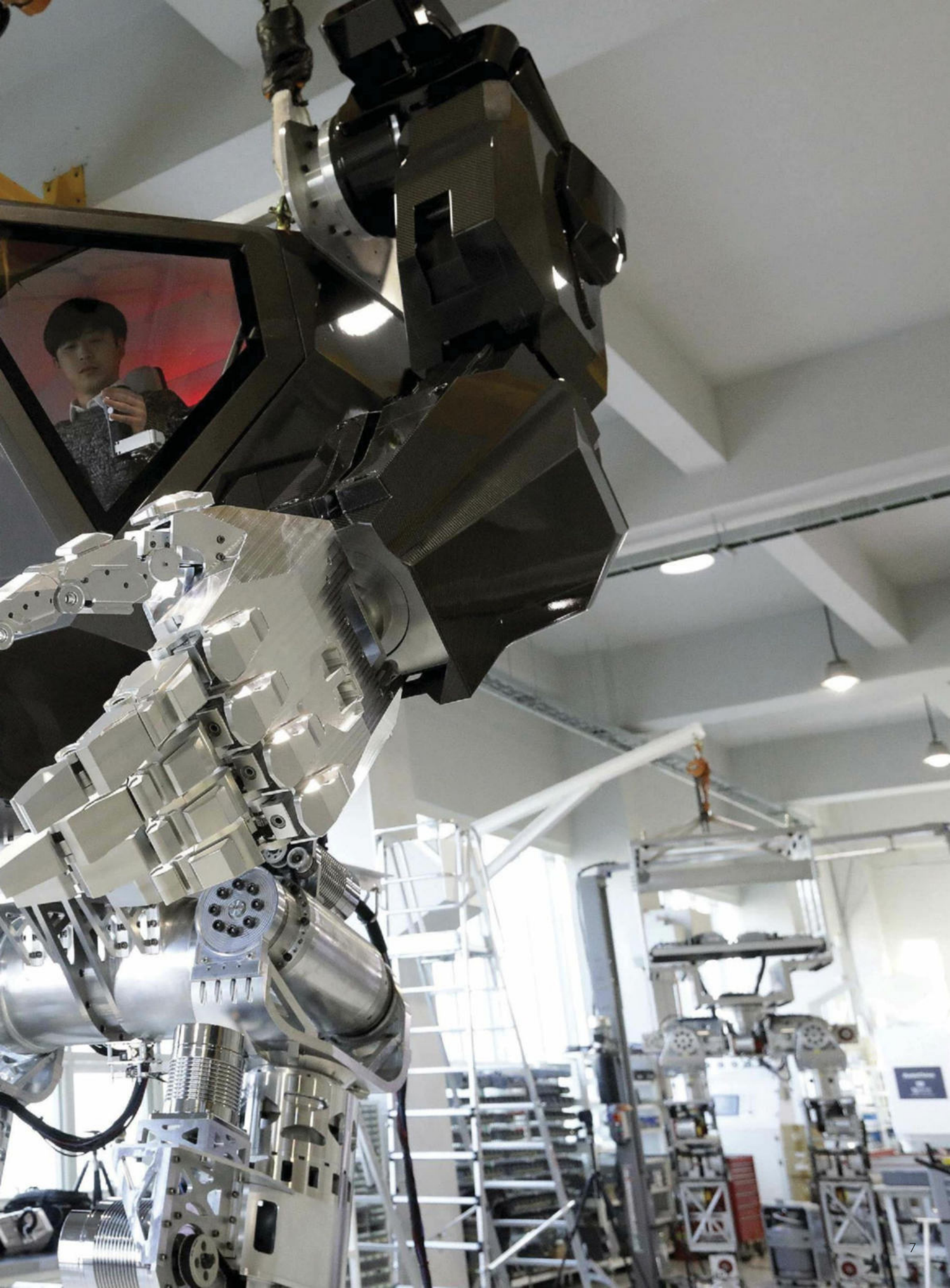
Say hello to Method-2, a four-metre-high mech that has been built by Korea Future Technologies. It's hoped that it will one day be able to enter hazardous regions where humans cannot venture.

This latest model was completed at the end of last year with the help of conceptual designer Vitaly Bulgarov. Its sci-fi appearance is no accident, as Bulgarov's previous projects include the films *Transformers 4* and *Terminator: Genisys*.

Method-2 currently obeys the commands of a human pilot, who sits inside and controls the mech using hand gestures and a pair of joysticks. Despite its size, the bot is surprisingly supple. Its articulated hand and finger joints should one day allow it to carry out precise movements. Currently, the 1.3-tonne machine has to be tethered to a power supply, but there are already plans to take it into real-world scenarios such as disaster relief and cargo handling in the next few years.

PHOTO: GETTY







# Perfect storm

## PACIFIC OCEAN

Fasten your seat belts, it's going to be a bumpy ride. Photographer Santiago Borja, a pilot based in Ecuador, snapped this shot of a colossal cumulonimbus cloud from an altitude of over 11,000 metres, while flying across the Pacific Ocean.

Known as the 'King of Clouds', these huge formations are the only type of cloud to produce thunder, lightning and hail.

"Fuelled by strong ascending motion, parcels of moist air barrel upwards through the atmosphere forming deep cloud towers that can reach heights of 12 kilometres," says Amanda Maycock, a climatologist at the University of Leeds. "Eventually, the air reaches a layer with rapid changes in temperature. This acts like a lid preventing further ascent and causes the cloud tops to spread out into an anvil, which can be seen in this image."

Cumulonimbus cloud cells are associated with blizzards, torrential rain, and most commonly, tropical storms. So if you're flying through one, you can expect a bit of turbulence.

PHOTO: SANTIAGO BORJA LOPEZ









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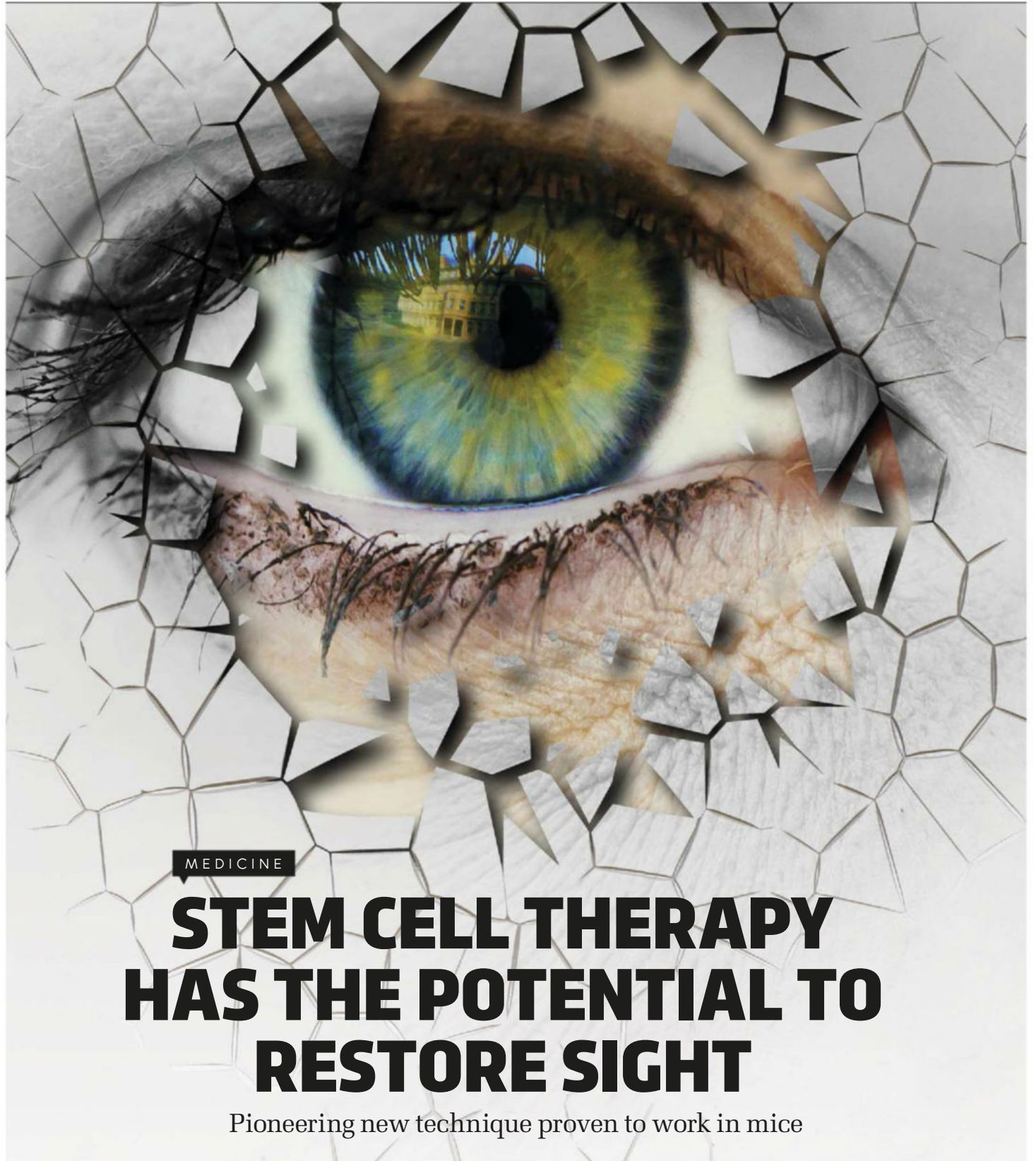


# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

FEBRUARY 2017

EDITED BY JASON GOODYER



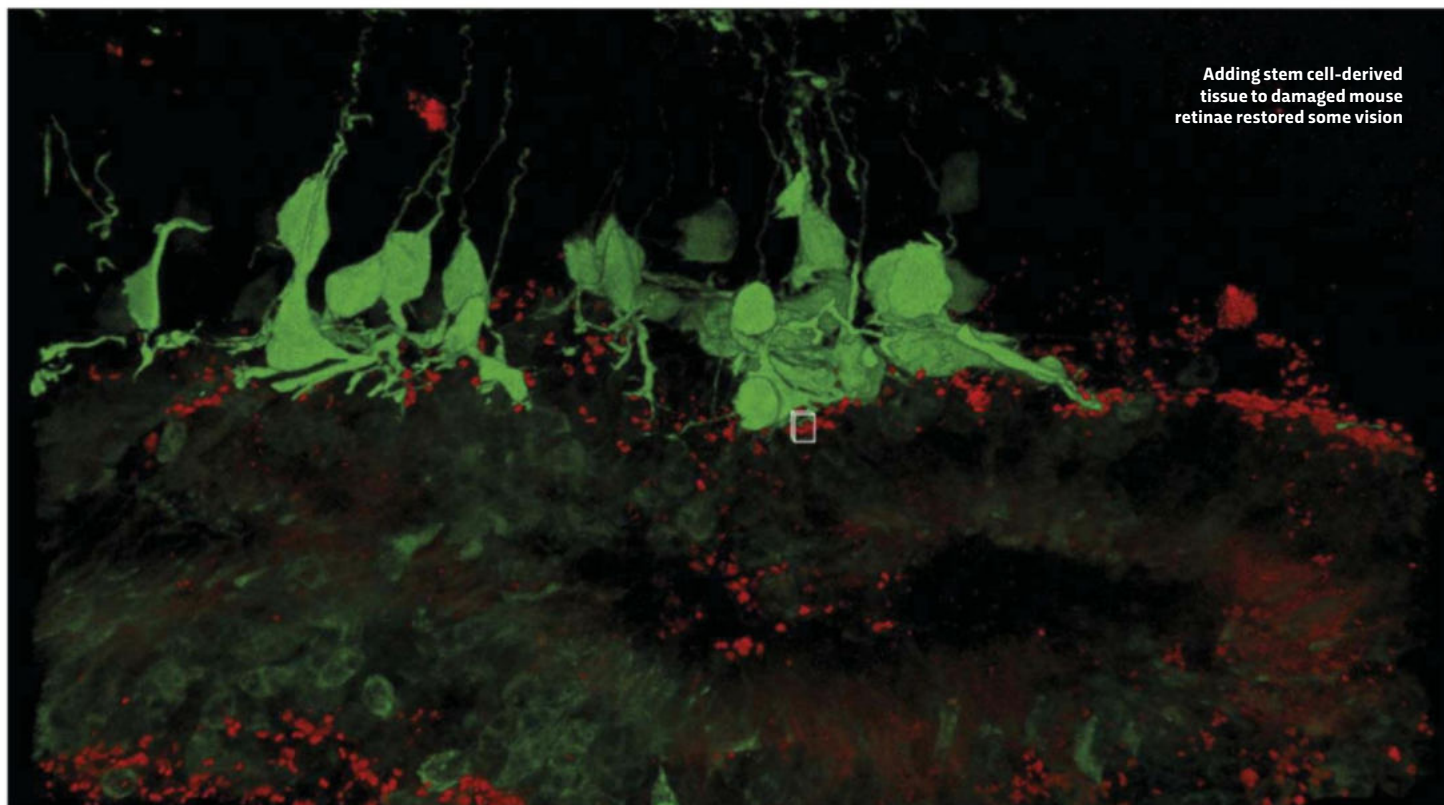
MEDICINE

## STEM CELL THERAPY HAS THE POTENTIAL TO RESTORE SIGHT

Pioneering new technique proven to work in mice

PHOTO: ALAMY





Adding stem cell-derived tissue to damaged mouse retinæ restored some vision

Say goodbye to your reading glasses. Researchers at Japan's RIKEN Centre for Developmental Biology have restored vision in mice with end-stage retinal degeneration – the leading cause of irreversible vision loss and blindness in elderly humans – by transplanting retinal tissue grown using stem cells.

Patients with conditions such as age-related macular degeneration and retinitis pigmentosa lose vision as a result of damage to the outer layer of light-sensitive photoreceptor cells in the eye. There is currently no cure for this, only therapies aimed at stopping the progression of vision loss.

The team genetically reprogrammed skin cells taken from adult mice to an embryonic, stem cell-like state, and then converted these into retinal tissue. When transplanted into mice with end-stage retinal degeneration, the stem cell-derived retinal tissue developed to form photoreceptors – specialised neurons within the retina that send vision signals to the brain.

“No one has really shown transplanted stem cell-derived retinal cells responding to light in a straightforward approach, as presented in this study, and we collected data to support that the signal is transmitted to host cells that send signals to the brain,” said researcher Michiko Mandai.

When the treated mice were placed in a box consisting of two chambers, with one rigged up to deliver electric shocks through the floor, they were able to see a warning light and avoid the shocks by moving from one chamber to the other.

“We showed that visual function could be restored to some degree by transplantation of the stem cell-derived retina,” said Mandai. “This means

“VISUAL  
FUNCTION  
COULD BE  
RESTORED  
TO SOME  
DEGREE”

that those who have lost light perception may be able to see a spot or a broader field of light again.”

Next up the researchers will test tissue derived from human stem cells in mice, with the ultimate goal of moving on to clinical trials in humans.

“It is still a developing-stage therapy, and one cannot expect to restore practical vision at the moment,” said Takahashi. “We will start from the stage of seeing a light or large figure, but hope to restore more substantial vision in the future.”

#### EXPERT COMMENT

Prof Robert MacLaren

*Professor of ophthalmology, University of Oxford*

“This study is exciting because it shows that a complicated part of central nervous system, such as the retina, could potentially be regenerated from something as simple as a skin cell. Furthermore, the engineered retinal tissue appears to be able to make connections to the brain after transplantation. Clinical treatments are still a long way off, but for patients with retinal degeneration, this provides some hope for the future.”





## MICROBIOLOGY

## DEEP-SEA MICROBES MAY BE MISSING LINK IN SEARCH FOR ORIGIN OF COMPLEX LIFE

Let us introduce Thor, Loki, Odin and Heimdall – our microbial ancestors dating back two billion years. A team at Uppsala University, Sweden has discovered several microbes carrying genes that were previously thought to be unique to more complex life forms, including humans.

The single-celled microorganisms, called archaea, were discovered in aquatic sediments collected at seven sites around the world, including hydrothermal vents in the Arctic Ocean and hot springs in Yellowstone National Park. The four species in question, named after Norse gods and known as ‘Asgard archaea’, are as different from one another as a tree is from a mushroom.

The finding supports a decades-old theory that complex life first arose when an archaeon consumed a bacterium, but the bacterium survived. The resulting arrangement proved to be beneficial to both, and the two previously separate

organisms evolved into life forms with cells and complex internal structures, called eukaryotes. All plants and animals are eukaryotes.

“The things which we thought made a eukaryote a eukaryote, [are what] we’re now finding in these new archaea,” said researcher Brett Baker. “We’re essentially rewriting the textbook on basic biology.”

So far, the archaea have only been identified by piecing their genomes together using separate bits of gathered genetic material. The team’s next goal is to grow them in the lab.

“It would be great if we could isolate or grow Asgard cells, and study them under the microscope,” said Thijs Ettema, a researcher who was involved in the project. “I am convinced that this will reveal more important clues about how complex cells evolved. Ultimately, our microbial ancestry will be uncovered.”

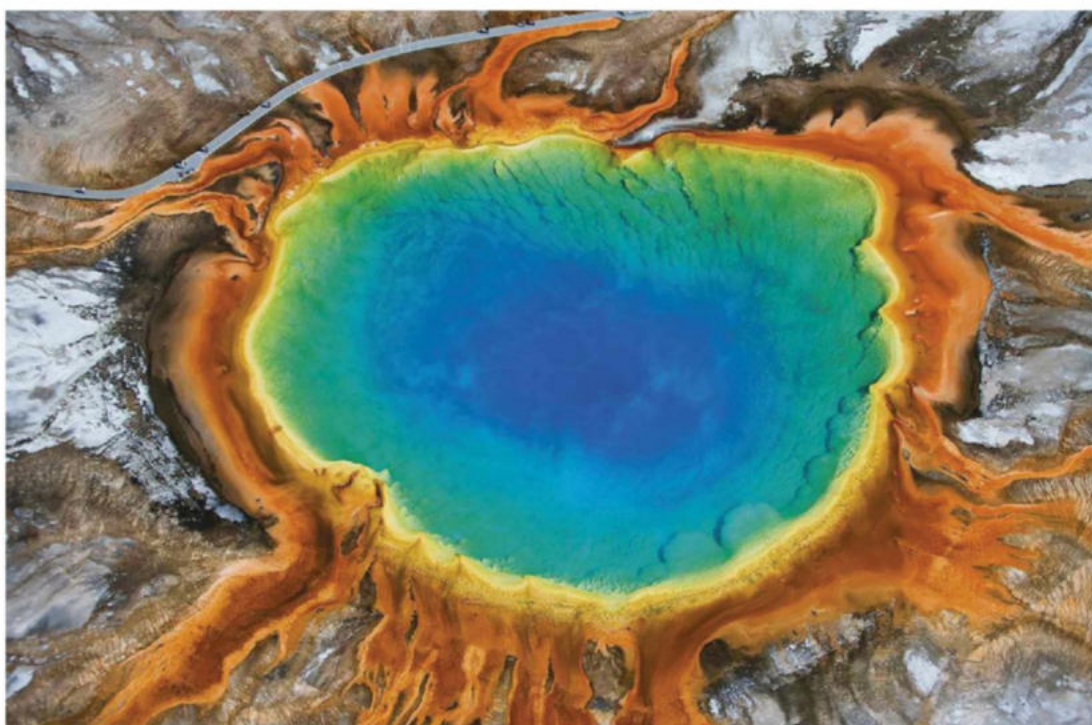
## IN NUMBERS

# 3-6 MONTHS

The length of time it took to hatch a dinosaur egg, a team from Florida State University has found. This long incubation period combined with the fact it took around one year for dinosaurs to mature could’ve contributed to their extinction, the researchers say.

# 13,045 km

The distance flown by a male Alaskan sandpiper in just one month in order to mate with as many females as possible, as tracked by a team at the Max Planck Institute for Ornithology, Germany.



Hot springs in Yellowstone housed the new species



## THE DOWNLOAD

## The mesentery

**What's that? A Netflix drama set in a medieval Italian monastery?**

Way off. It's a newly discovered organ found hiding in plain sight in the human digestive system by researchers at Limerick University Hospital.

**What is it?**

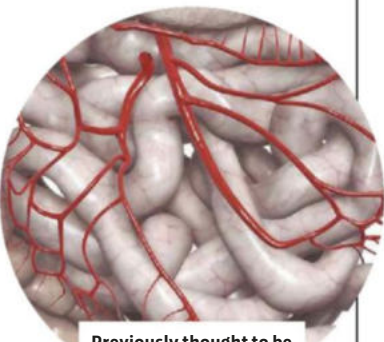
It's a group of folded tissues that connects the intestines to the wall of the abdomen. For hundreds of years it was thought to be made up of several sections, but new research has found it is a single, continuous structure.

**What does it do?**

All we know so far is that it carries blood between the intestine and the rest of the body, and helps keep the intestine in the right place.

**So what's next?**

The researchers now want to establish the exact function of the organ so that they can identify any possible diseases relating to it. This will usher in the new field of mesenteric science, they say.



Previously thought to be just a mass of tissue, the mesentery is actually an organ in its own right

## ZOOLOGY

# BABOON BARKS AND GRUNTS CONTAIN CLUES TO THE ORIGINS OF LANGUAGE

The grunts, barks and wahoos of baboons contain distinct vowel-like sounds similar to human speech, suggesting language may have begun to evolve 25 million years ago.

After analysing 1,335 spontaneous vocalisations produced by 15 male and female Guinea baboons in different social contexts, researchers from Grenoble Alpes University in France found that baboons produce five sounds that have close similarities with vowel sounds used in human speech. Humans form each vowel by precisely controlling the tongue's position in the vocal tract.

It was previously thought that the voice box of

non-human primates such as baboons was too high in their necks to produce the distinct vowel sounds found in human languages. This would mean language must have originated within the last 70,000-100,000 years. However, the new findings suggest that spoken language may have

Baboons use vowel-like sounds, just like we do

**"BABOONS PRODUCE FIVE SOUNDS THAT HAVE CLOSE SIMILARITIES WITH VOWEL SOUNDS USED IN HUMAN SPEECH"**

evolved from capacities already possessed by our last common ancestor with baboons, some 25 million years ago.

By examining the vocal tracts of two baboons that died from natural causes, they also found that baboon tongues have the same muscles as human tongues. This suggests that these monkeys use similar tongue movements to humans to form each of the sounds.

"Similarities between humans and baboons suggest that the vowels of human speech probably evolved from ancient articulatory precursors that were passed on and refined all along the hominid line," said researcher Joel Fagot.



PHOTOS: SCIENCE PHOTO LIBRARY, GETTY, NASA



## SPACE

## COULD MARTIAN SETTLERS LIVE IN ICE HOUSES?

Step aside, Nanook: NASA has announced a Mars base concept that reinvents the igloo.

The variable distance between Mars and Earth means astronauts may have to stay on the surface of the Red Planet for many months. That means living quarters are required to keep the crew safe from wildly varying temperatures and radiation.

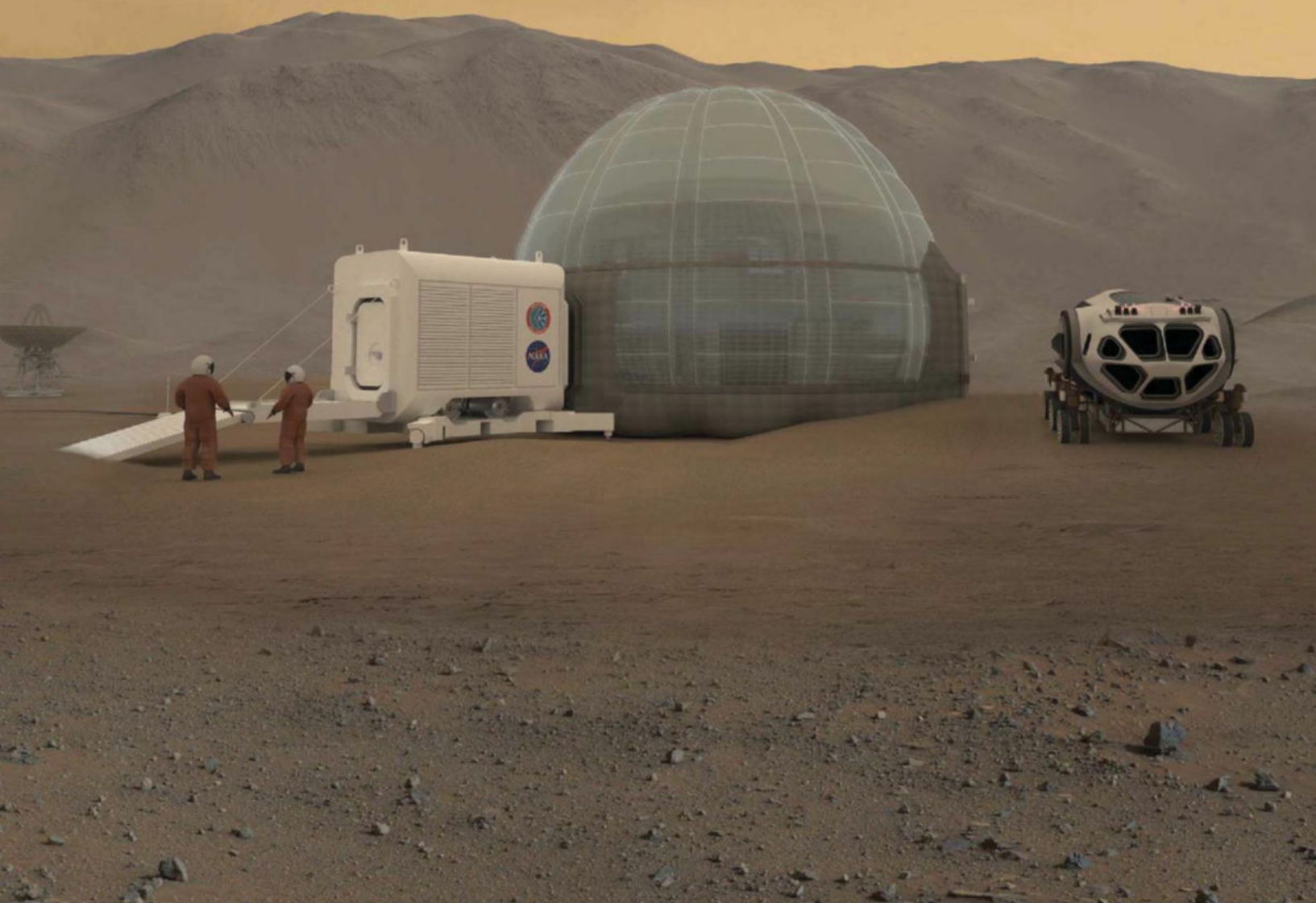
Dubbed the Mars Ice Home, the new structure consists of a doughnut-shaped inflatable living area, surrounded by a dome filled with water. This freezes to form a thick wall of ice, providing more than enough protection from the dangerous levels of cosmic rays that bombard the surface of Mars – and, if split into hydrogen and oxygen, the water can double as fuel for the return rocket.

“All of the materials we’ve selected are translucent, so some daylight can pass through and make it feel like you’re in a home and not a cave,” said lead researcher Kevin Kempton.

Because the structure is light plastic, this base would be easy to transport, while the heavy content – the water – could be sourced on Mars. The habitat would be sent ahead of the astronauts and gradually filled from water deposits on the planet. It’s estimated that, at a likely cubic metre a day, this would take 400 days.

The Ice Home is just one of the base concepts investigated by NASA’s Langley Research Center, holding out the hope of a comfortable stay on Earth’s nearest planetary neighbour.

The Mars Ice House is just one of several ideas for constructing temporary shelters for astronauts on possible future Mars missions







Egyptian fruit bats are social animals and roost together in caves – can you spot the yawning one?

## NATURE

## BATS' CHIRPING DEMYSTIFIED

Just call it bat chat. Researchers from Tel Aviv University have managed to decipher bat calls, to find out exactly what they're talking about.

The team spent 75 days monitoring a group of 22 Egyptian fruit bats (*Rousettus aegyptiacus*) round-the-clock. After recording tens of thousands of calls, the researchers used a machine-learning algorithm to pick out various details in the sounds. They found that they could identify which bats were calling, which bats the calls were being directed at, and could even get an idea what the animals were saying.

"When you enter a bat cave, you hear a lot of 'gibberish', a cacophony of aggressive bat noise," said Prof Yossi Yovel, who led the study.

"THE BATS'  
BICKERING  
WAS OVER  
FOOD,  
PERCHING  
SPOTS OR  
MATING"

"Previous research presumed that most bat communication was based on screaming and shouting. We wanted to know how much information was actually conveyed – and we wanted to see if we could, in fact, extract that information," he added.

The researchers found the majority of the bats' bickering was over food, perching spots or mating attempts. They were also able to identify different intonations indicating the greetings of a 'friend' or a 'foe'.

According to the researchers, further study of animal calls could help to piece together the evolution of communication and even the birth of human language.



## PHYSICS

# CERN RESEARCHERS SHINE A LIGHT ON ANTIMATTER

If science fiction were to be believed, antimatter would be everywhere: from the USS Enterprise's power source to the giant bomb in Dan Brown's *Angels & Demons*. In real life, however, it's much more elusive. But that may be about to change. ALPHA, an international collaboration of CERN-based researchers, has observed the light spectrum of antimatter for the first time.

Antimatter is identical to matter particles, such as electrons and protons, but has the opposite charge. It is tricky to handle as it annihilates the moment it encounters ordinary matter, leaving only pure energy behind.

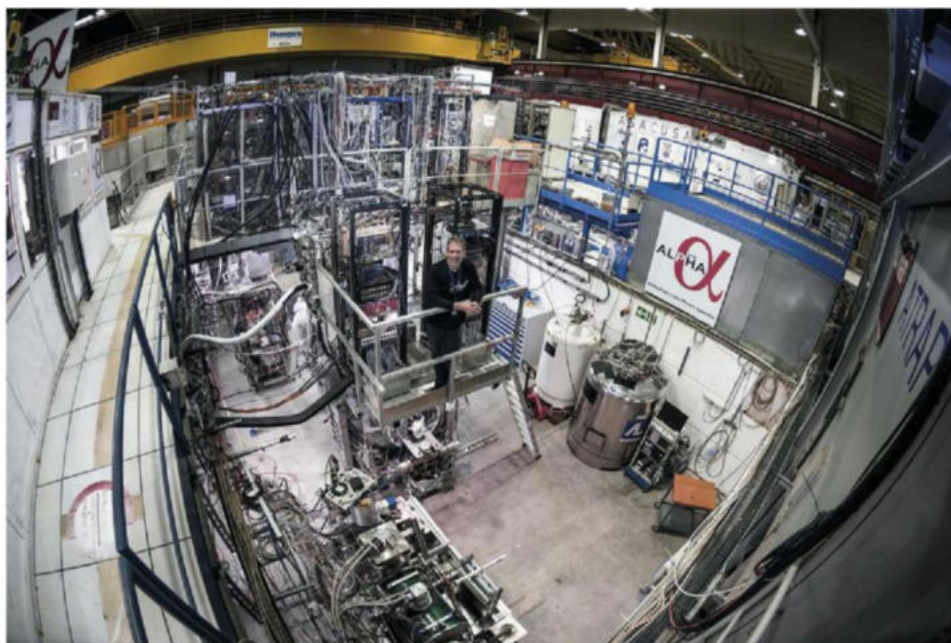
ALPHA has been working on combining positrons with antiprotons to produce atoms of antihydrogen, which are slippery customers. But by using a clever trap to capture the antihydrogen particles, they can be studied. "We have designed a very

special magnetic trap that relies on the fact that antihydrogen is a little bit magnetic," said Jeffrey Hangst, the collaboration's spokesperson.

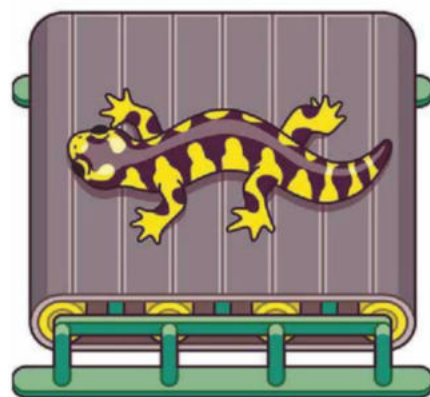
Atoms are identified by the wavelengths of light they absorb or give off when electrons make a jump between different energy levels within them. The ALPHA collaboration found that, within the limits of the experiment, the spectrum for the simplest electron jump in antihydrogen was identical to ordinary hydrogen. This is an important discovery, because if there were measurable differences between antihydrogen and hydrogen, then the basic principles of particle physics would be broken.

There is plenty more to discover – for example does antimatter fall or up or down under gravity? – as the CERN team continues to explore this remarkable substance.

The ALPHA experiment at CERN



## THEY DID WHAT?!



## SALAMANDERS WALK FOR MILES ON TREADMILLS

### What did they do?

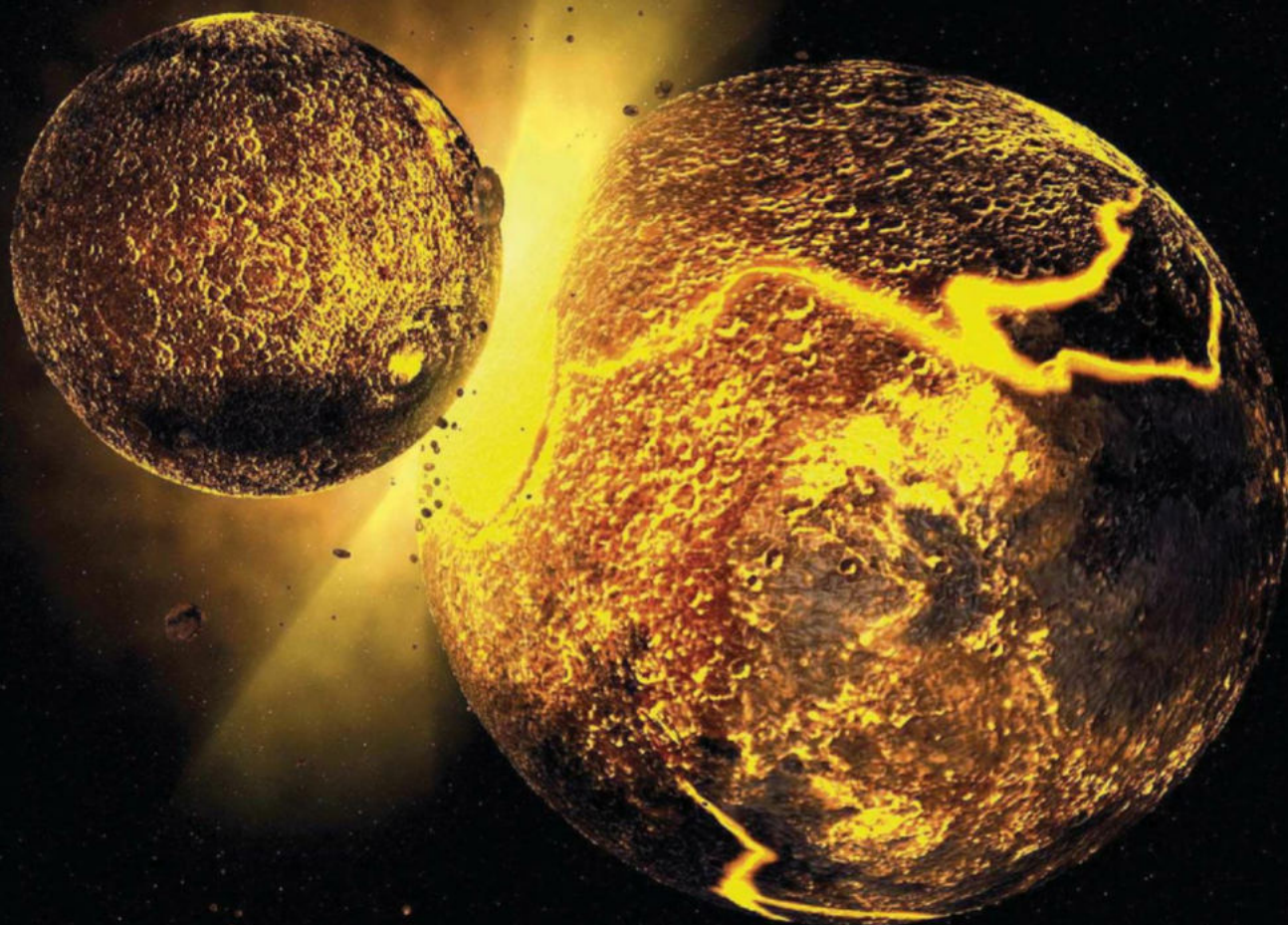
Researchers from Ohio State University put two types of mole salamander on a treadmill, one type was born via male/female sexual reproduction, the other asexually from a single female, and 'encouraged' them to walk by poking them in the backside.

### Why did they do that?

The team wanted to know more about how the salamanders procreate in order to help with conservation efforts.

### What did they find?

The salamanders that were born via male/female reproduction were willing to walk up to four times as long as their asexually produced counterparts with some individuals trekking for more than 14 kilometres (nine miles). The difference may be due to the asexually produced salamanders having less varied genes and lacking in those responsible for providing them with energy, the researchers say.



## ASTRONOMY

## COULD THE MOON HAVE FORMED FROM DOZENS OF MINI MOONS?

If you were to travel back tens of thousands of years in time and look up, you may well see a sky full of mini moons.

Researchers from the Technion-Weizmann Institute of Technology have proposed a theory suggesting that our current Moon may be the latest in a long line of moons that orbited Earth in the past, each created by an impact from giant asteroids.

“Our model suggests that the ancient Earth once hosted a series of moons, each one formed from a different collision with the proto-Earth,” said researcher Hagai Perets. “It’s likely that such moonlets were later ejected, or collided with Earth or each other to form bigger moons. We believe Earth had many previous moons. A previously formed moon

---

“OUR MOON  
MAY BE THE  
LATEST IN A  
LONG LINE  
OF MOONS  
THAT ORBITED  
EARTH IN  
THE PAST”

could therefore already exist when another moon-forming giant impact occurs.”

The team ran almost 1,000 computer simulations of different scenarios of objects striking Earth, and found it would take around 20 collisions to get the job done. According to this model, the Earth experienced many giant impacts with other bodies during the last stages of its growth, with each contributing more material to the proto-moon until it reached its current size.

“It’s likely that small moons formed through the process could cross orbits, collide and merge,” said researcher Raluca Rufo. “A long series of such moon-moon collisions could gradually build up a bigger moon – the Moon we see today.”

PHOTOS: SCIENCE PHOTO LIBRARY, IVAN DE ARAUJO ILLUSTRATION: RAJA LOCKEY



## NATURE

## KILLER INSTINCT LOCATED IN MOUSE BRAINS

Just call it a kill switch. Researchers at Yale University have isolated the brain circuitry that coordinates predatory hunting in mice.

The team used optogenetics, a method of engineering specific neurons to fire when illuminated with laser light, to activate two separate sets of neurons in the mice's amygdala, the brain's centre of emotion and motivation. One set caused the animals to pursue prey, and another caused them to flex their jaw and neck muscles to bite and kill.

When the laser was off, the mice behaved normally. But as soon as the laser was turned on they burst into action, pursuing and biting almost anything they came across, including inanimate objects such as bottle caps, toy insects and wooden sticks.

"We'd turn the laser on and they'd jump on an object, hold it with their paws and intensively bite it as if they were trying to capture and kill it," said researcher Ivan de Araujo,

While the animals did not attack other mice in the cage, the team found, perhaps unsurprisingly, that hungry mice were more aggressive in pursuing and biting the prey.

"There must be some primordial subcortical pathway that connects sensory input to the movement of the jaw and the biting," de Araujo continued. "The system is not just generalized aggression. It seems to be related to the animal's interest in obtaining food."

The team now aims to investigate how the two behaviours – pursuing and killing – are coordinated.



Once, he was ordinary Bill Mouse. But after exposure to lasers, he was transformed into Bill 'The Killer' Mouse



### SAUNA GOERS

A 20-year study at the University of Eastern Finland has found that those taking regular saunas are two-thirds less likely to be diagnosed with dementia. The effect is thought to be due to the relaxation it provides.

### ODONTOPHOBES

If the sound of the dentist's drill leaves you a quivering wreck, read on. Researchers at Kings College London have found that Alzheimer's drug Tideglusib can stimulate production of dentine, potentially removing the need for fillings.

### GOOD MONTH

### BAD MONTH

### SELFISH SO-AND-SOS

Older people who care for others during their dotage live longer than their less helpful counterparts, researchers at the University of Basel have found. The effect is due to the mutual emotional support provided, they say.

### MIGRATORY BIRDS

The early bird doesn't always catch the worm. Each 1°C rise in global temperature can mean birds reach summer breeding grounds a day early, a team at the University of Edinburgh has found, which may cause them to miss out on food sources.



## SPACE

## BLACK HOLES BELCH OUT PLANET-SIZED BALLS OF GAS

Nothing ever escapes a black hole, right? Wrong. New research has revealed that Sagittarius A\*, the supermassive black hole which lies at the heart of the Milky Way, regularly issues forth balls of gas that can be as big as a planet.

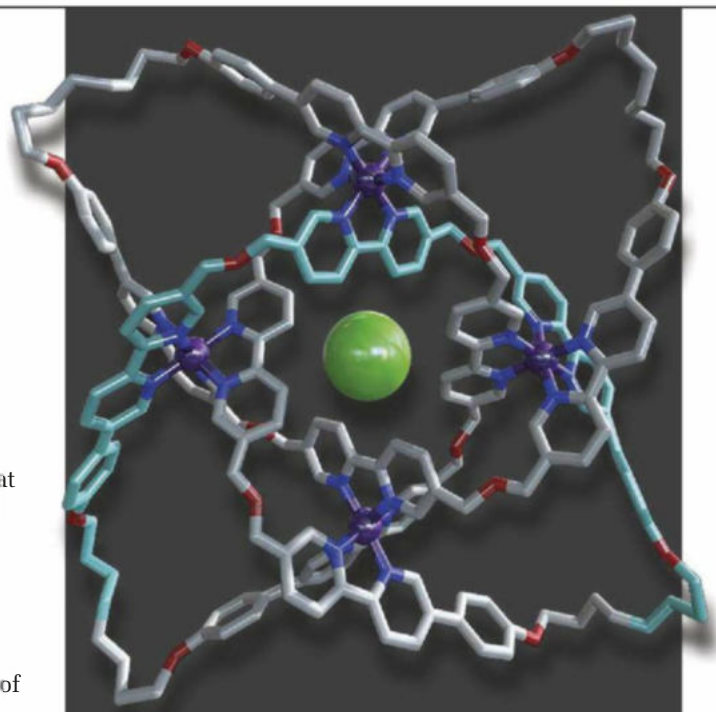
Strictly speaking, these don't actually come from the black hole itself, because their point of origin lies outside the event horizon. What happens is that, every few thousand years, a star will come too close the black hole and be ripped apart by its ultra-high gravity. But the black hole won't necessarily consume *all* of the star's gas – some of it can escape, whipping outwards in a long stream.

Previously, it was believed that these streamers would eventually disperse. Now, however, new research by undergraduates Eden Girma and James Guillochon at the Harvard-Smithsonian Center for Astrophysics in the USA has shown that the gas can in fact cluster together again, forming hundreds of planet-sized globules that are then flung across the Milky Way at speeds of up to 10,000km/s, with most eventually exiting the Galaxy entirely.

As all galaxies are now believed to have a supermassive black hole at their centres, it's likely that there are countless such 'cosmic spitballs' weaving their way across the Universe – although wandering or 'rogue' planets still outnumber them by around 999 to one.



Planet-sized balls of non-burning gas known as 'brown dwarves' are common, but now it seems they have some more energetic cousins



## MATERIALS

## SCIENTISTS TIE TIGHTEST-EVER KNOT

If you thought untangling your phone charger from the mass of leads and cables in your desk drawer was tricky, spare a thought for David Leigh and his team at the University of Manchester, who recently had to unpick a knot that featured eight 'crossings' despite measuring just 20 millionths of a millimetre across.

It was entirely their own fault, mind you, because they'd tied the record-breaking knot in the first place. Leigh and his colleagues are researching different ways of knotting together molecular strands of high-tech polymer strands, with a view to creating new materials.

Most of today's strong, synthetic materials, such as Kevlar, are made up of molecular rods that line up in a parallel structure. It's hoped that by knotting or weaving polymer strands together, we may be able to create new materials that are just as strong and durable, but that are simultaneously lighter and more flexible.

"Tying knots is a similar process to weaving, so techniques developed to tie knots in molecules should also be applicable to the weaving of molecular strands," said Leigh. "Some polymers, such as spider silk, can be twice as strong as steel, so braiding polymer strands may lead to new generations of light, super-strong and flexible materials for fabrication and construction."



## BIOLOGY

# SLIME MOULDS CAN SHARE INFORMATION

Imagine if bumping into someone in the street meant you knew everything they knew. A French team has discovered that when two slime moulds fuse together, they pool their knowledge. This knowledge is then retained by both organisms even if they're split into two.

It's only been known for a short while that slime moulds are capable of learning at all. Last year, a team at the National Centre for Scientific Research (CNRS) in Toulouse showed that slime moulds can become habituated to bitter but harmless substances such as quinine or salt, learning and remembering that it is safe to cross a bridge coated in these substances to reach a food source. The same team is behind the new research, which studied interactions between

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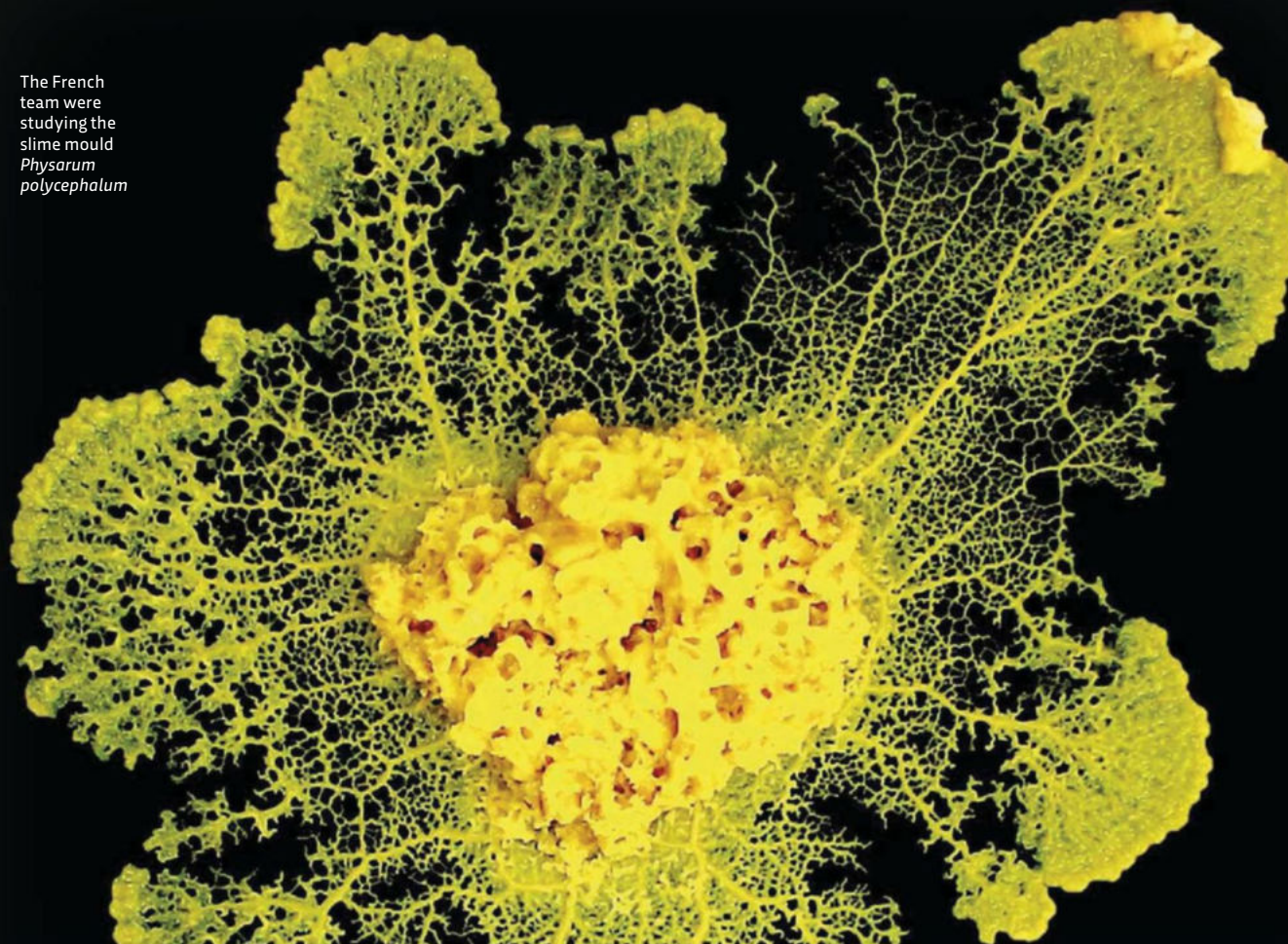
**"WHEN  
TWO SLIME  
MOULDS  
MEET, THEY  
CAN FUSE  
INTO ONE"**

these habituated moulds and non-habituated or 'naive' moulds.

When two slime moulds meet, they can fuse into one. The scientists found that if a naive and an habituated mould fused, the new mould would also cross a salt-covered bridge with impunity, whereas a mould formed by two naive moulds fusing would hang back. What's more, if the fused moulds were then separated, the previously naive moulds were still happy to cross the salty bridge. In other words, their habituated former partner had passed on its knowledge during the fused period.

The team is now investigating how this process occurs, and is currently focusing on a 'vein' that appears during the fusion stage.

The French team were studying the slime mould *Physarum polycephalum*



## DINOSAURS

# CLUES TO THE EVOLUTION OF BIRDS' BEAKS FOUND IN ANCIENT DINOSAUR FOSSILS

It looks like this dinosaur just moved up the pecking order. The discovery of several fossils belonging to a small ostrich-like dinosaur called *Limusaurus inextricabilis* (inextricable mud lizard) has given researchers a clue to the origin of modern birds' beaks. A total of 19 skeletons of the dinosaur have been found in mud traps in China's Xinjiang province. They have been dated to about 159 million years ago, during the Jurassic Period.

With the unusual luxury of comparing remains of all ages, from baby dinosaurs to adults, a team from China and the US has pieced together a remarkable change that occurred as *Limusaurus* grew up. They found that the young dinosaurs had teeth, but by the time the animal reached its adult size of 1.5 metres in length, all of its teeth had fallen out leaving behind a bird-like beak.

"This discovery is important for two reasons," said lead researcher James Clark. "First, it's very rare to find a growth series from baby to adult dinosaurs. Second, this unusually dramatic change in anatomy suggests there was a big shift in *Limusaurus*' diet from adolescence to adulthood."

It seems likely that the young *Limusaurus* enjoyed a diet that included meat, but the mature animals were vegetarian and so didn't need sharp teeth to cut through flesh. This is also backed up by changes in the mineral content of the animals' bones.

At first sight, modern birds seem different from our mental images of dinosaurs. But as we learn more, it seems that some of the extinct beasts closely resembled our garden visitors.



If the baby dinosaurs ate a different diet to the adults, there would have been less competition over food

## WHAT WE LEARNED THIS MONTH

### STRESS CAN MAKE DOGS GO GREY

It's not only highly strung humans who are prone to the 'salt and pepper' look.

A stressful life can also make your pooch's muzzle turn grey, researchers from Northern Illinois University have found.

### AFTERNOON NAPS COULD IMPROVE THINKING AND MEMORY

Having a quick afternoon doze may not seem like the best way to impress your boss, but it may help improve your work. Getting 60 minutes' shuteye in the afternoon can make your brain perform as if it were five years younger, a team at the University of Pennsylvania has found.

### ANTARCTIC ICE IS ON THE MOVE

A giant chunk of ice the size of Norfolk could be about to shear off from the Larsen C ice shelf, according to satellite observations by the British Antarctic Survey.

### ENJOYING LIFE CAN HELP US TO LIVE LONGER

After following the lives of 10,000 adults with an average age of 63 for four years, a team at University College London found the chance of death was up to 24 per cent lower in those reporting the highest levels of enjoyment.

PHOTO: PORTIA SLOAN





# HOW WE'LL KEEP THE LIGHTS ON

*Is Britain's grid ready to cope with the energy crisis of tomorrow?*

If you're reading this with the lights on, count yourself lucky. Before long you might be reading it by candlelight, if a new report on Britain's electricity network is any guide.

The study, which was published by the British Infrastructure Group (BIG), states that the nation's power supplies can barely cope with current demand, the National Grid's 'safety margin' – the value between demand and available supply – having shrunk to just 0.1 per cent this winter. "By next winter," the report warns, "the Christmas lights could go out".

How seriously should we be taking all this? Not very, to be frank. First of all, despite its impressive name, the BIG isn't some authoritative academic think-tank. It's a loose grouping of MPs keen to draw attention to the dreadful state of British infrastructure, from our roads and airports to our broadband.

A laudable aim, no doubt, but one not helped by making statements that don't really stand up. Take that scary claim about the National Grid's safety buffer being just 0.1 per cent. It appears in the executive summary... but then it mysteriously changes to 1 per cent elsewhere in the report.

That's still not exactly a huge margin, and would still be cause for alarm – were it true. But according to the National Grid, the actual safety margin is well over 6 per cent, and perfectly able to cope with any unexpected breakdowns and freak weather.

So will the lights go out next Christmas? Well, they might, but it's much less likely than the BIG report might lead us to think.

Still, the report is spot on about one thing: the country's energy infrastructure isn't as robust as it could be.

Governments of every political hue have been repeatedly warned of the need for urgent action by the likes of the Royal Academy of Engineering, the Institution of Civil Engineers and the Energy and Climate Change Select Committee.

Climate change targets have made the need for action even

**"WE ALL USE  
A LOT OF  
ELECTRICITY  
WHEN  
IT'S NOT  
ACTUALLY  
NEEDED"**



more pressing. That's because renewables like wind farms don't provide a steady flow of power.

If the wind drops – or blows so strongly that the turbines can't cope – the National Grid has to intervene to balance demand and supply.


The obvious way to solve the problem is to build more power stations. The trouble is that this takes years and colossal sums of money. Storing energy via batteries, compressed air or pumped water is another option, but this also takes time and money.

Fortunately, there's a third option: just allow the lights to go off.

The idea isn't as crazy as it seems. We all use a lot of electricity when it's not actually needed. From boilers in homes to furnaces in factories, there are millions of devices that can be switched off for a short time – so short, in fact, that they'd not be missed. A freezer, for example, doesn't thaw out the moment it's switched off.

Totted up across the nation, all these small savings amount to a hefty reduction in demand – and an instant increase in the safety margin without needing new and expensive power stations or storage technology.

National Grid is on to this already. It is persuading hotel chains, supermarkets and others to join a scheme that allows their energy use to be tweaked remotely to preserve the safety margin at times of high demand. It's currently testing technology developed by the Finnish company Reactive Technologies that allows instructions to be sent down wires to any electrical device. That opens the way for every home and office to save energy and money without doing a thing.

It's a neat solution to a tough problem. And it also looks set to be yet another example of why dire predictions so often fail to come true: they underestimate the power of human ingenuity. 

Robert Matthews is visiting professor in science at Aston University, Birmingham.

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# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

## CES 2017 SPECIAL

### AMPED UP TO THE MAX

*Avatar* technology comes  
to the real world

One of the biggest crowd-pullers at CES (the biggest new tech showcase of the year) was this prototype of a huge robotic exoskeleton. Built by Furrion Robotics, the Prosthesis weighs more than three tonnes. The 4.2m-tall, 4.8m-long mech is

operated by a human pilot, just like the AMP suits in the movie *Avatar* – but its raison d'être is to race other mechs, rather than obliterating blue-skinned aliens. Although of course, that will require someone to build another mech for it to race against...

## NISSAN AND NASA CLEAR ROADBLOCKS TO A DRIVERLESS FUTURE

Nissan plans to get autonomous cars driving on our city streets by 2020, with a little help from NASA. In fact, you can stick this date in your calendar, as this seems to be when the big car companies attending CES say we'll see autonomous models in their showrooms.

One of the biggest roadblocks to this driverless future is, well, roadblocks. When a driver encounters an obstruction, like road works, they have to break the rules of the road to get around: crossing a white line or driving towards oncoming traffic. But how do you code an AI to do the same thing – to act against its own programming? Nissan thinks it has found an answer – on Mars.

The Mars Curiosity Rover has been pootling about the Red Planet's surface without a driver for almost five years. Though there aren't many building sites or cyclists on Mars, Curiosity has to be able to handle the unexpected. Rather than depend wholly on the rover's AI, when Curiosity gets stuck it calls a human operator back on Earth.

Nissan intends to do the same with SAM, their Seamless Autonomous Mobility system. When a driverless car encounters an obstacle it can't navigate within its programming, it'll call up a 'Mobility Manager,' who will access the car's cameras and location, and pull up the most accurate mapping data the system can find. From there the remote pilot can 'paint' a new, safe route around the obstacle, saving each new solution at a given location to allow for a quicker response the second time around.

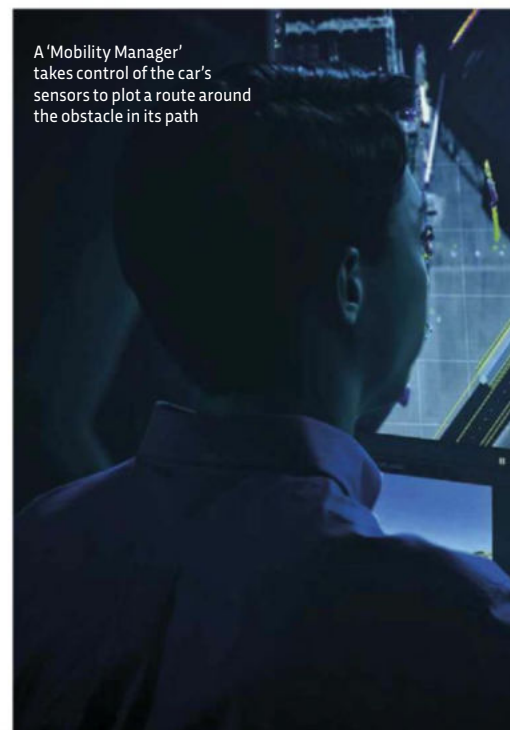
### TRULY DRIVERLESS VEHICLES

At CES, we were shown a live demo of the tech at a NASA facility, where the whole procedure took under a minute, and the data transfer appeared to be seamless. Of course we were concerned, given that we seem to lose all mobile phone signal on much of the M25, that connectivity would be an issue. But Nissan says that the link will be optimised to handle delays – after all, it's worked for interplanetary use before.

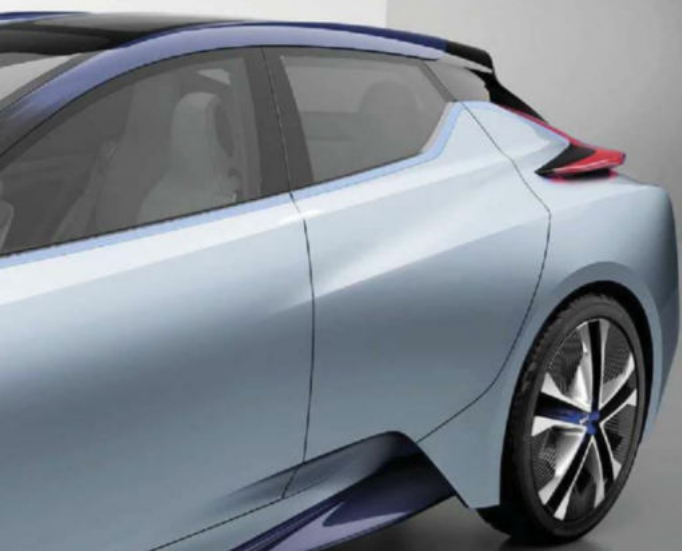
It might feel slightly counter-productive to get drivers to help us drive driverless cars, but SAM is the only system we've seen so far that could potentially remove the need for someone to sit behind the wheel. Nissan is also partnering with Microsoft to provide Cortana-based voice control in its car, with the bonus that Cortana's voice recognition should help make the entire system more secure.



A 'Mobility Manager' takes control of the car's sensors to plot a route around the obstacle in its path







The Intelligent Mobility Concept car from Nissan would use SAM, the car manufacturer's Seamless Autonomous Mobility system

## EVERYONE WANTS TO TALK TO ALEXA

This year's CES was positively bursting with gadgetry that works with Amazon's AI personal assistant Alexa – the Siri/Cortana-like 'voice' of Amazon Echo. Ranging from an outright Echo competitor (the Lenovo Smart Assistant) to Ford's SYNC3 in-car infotainment system, via robot vacuum cleaners, security cameras, Huawei's Mate 9 phone and 'smart' light bulbs, plugs and kitchen appliances galore, there were over 30 such products on display – more than the number of Siri or Google Home-enabled devices put together.



## GARDENING FOR GEEKS

If you fancy growing your own food but are hampered by not having a garden, you'll love this invention from Estonia's Natufia Labs. The Kitchen Garden is an indoor incubator that'll let you grow herbs and vegetables inside a high-tech hydroponic cabinet with a footprint of just 590 x 580mm. It's equipped with an array of sensors that send data about growing conditions to a smartphone app, and it even plays ambient and classical music to the plants to promote growth.



## WIRELESS POWER AT A DISTANCE

Imagine being able to charge your laptop, phone or tablet from a distance. That's the promise offered by WiTricity, a new wireless charging technology developed by two professors at MIT.

WiTricity uses a technique the professors first demonstrated in 2007, which makes use of natural resonant frequencies. This is the

phenomenon whereby a wine glass will shatter if an opera singer hits a certain note, because objects resonating at their natural frequency can take in much more energy. Since it uses a power source and capture device with similar natural frequencies, WiTricity's system enables faster, more efficient power transfer over greater

distances than existing wireless charging systems that rely on electromagnetic induction alone.

There's no word yet as to when WiTricity might be available as a consumer product, but Dell has already announced its next generation of laptops will support the tech, and other manufacturers are expected to follow suit.

## ULTRA-PERSONAL AUDIO SYSTEM

French company Akoustic Arts has developed a directional loudspeaker called A that only one person can hear at a time – without needing headphones.

A works by transposing sound frequencies, shifting audible sound into the ultrasonic realm. The resulting ultrasonic signal is then fired out like a laser beam from the A, at which point the signal will transpose itself back into audible sound but, crucially, retain its ultra-directional nature. The result is a speaker that lets you listen to loud music without disturbing those around you.

A smashed its Indiegogo funding target last year, but there's no word on a release date – though as the product was on show at CES, it's presumably not far off. We're quite excited, as we'll no longer have to suffer editor Dan's Justin Bieber habit.

**KEEP  
THE NOISE  
DOWN**





## OFFICE SILENCER

French company Orfea Acoustique has developed Silent Space, which is essentially a noise cancellation system for entire rooms rather than your headphones.

Designed for use in open-plan offices and other shared workspaces, the Silent Space system consists of a central controller, plus a number of satellite speakers (or 'diffusers', as Orfea calls them). The controller unit analyses the timbre and levels of ambient sound in the room, then instructs the diffusers to pump out a masking signal to match. These unobtrusive tones will cancel out the general hubbub of office life, such as the clank and whirl of the

printer, or the telephone chatter of the sales team across the room.

The result, says Orfea, is that "a virtual cocoon is created around each co-worker... which results in the feeling of a more private work space." The company goes on to claim that this will lead to a significant reduction in stress, fatigue and irritation among staff, and ultimately to reduced absenteeism.

And because prevention is better than cure, you can also add a 'collective noise indicator' that lights up to show how loud background noise in the room really is – hopefully encouraging your colleagues to keep their voices down a bit!



## THE INTERNET OF DAFT THINGS

There was no shortage of, ahem, 'surprising' IoT tech at CES...



French start-up Uzer was showing off **Eugene**, a smart kitchen bin that uses a barcode scanner to encourage you to recycle product packaging; it can also add the item to your next online shopping order.

Also on show was **Oombrella** – an umbrella equipped with air pressure, temperature, humidity and light sensors that gives you up to 15 minutes' notice of imminent rain. Because we all have our brollies out when it's dry...



L'Oreal was at CES demonstrating **Hair Coach**, a smart hairbrush with a built-in microphone, gyroscope and altimeter that listens for the sound of split ends breaking and tells you off (via Bluetooth and an app) for getting your brushing technique wrong.

But perhaps our 'favourite' was **Kissenger** – a prototype silicon iPhone add-on that uses pressure sensors and actuators to mimic the feel of a distant loved one's kiss. Frankly, hitherto unsuspected heights of unnecessary wrongness are being scaled here...



# WANTED!

CES 2017 SPECIAL

The onboard camera gives you a bird's eye view – in VR form



## PAPER PLANE

### POWERUP FPV

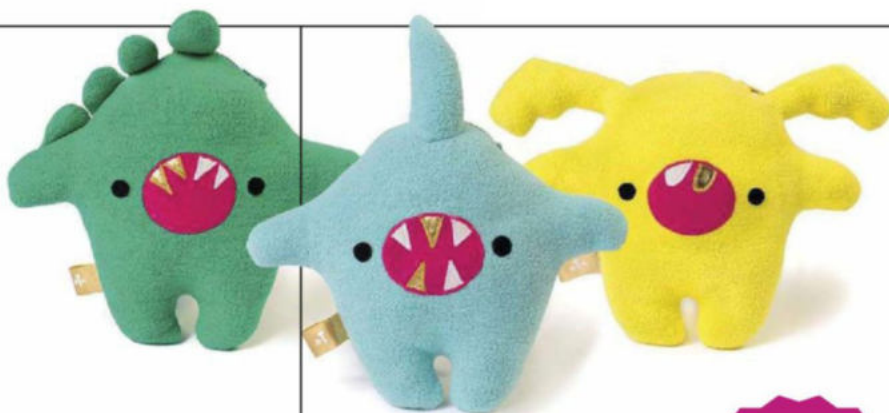
This assemble-it-yourself drone will give you a bird's-eye view of what it's like to fly. First build the plane, using the supplied templates or your own design. Next, put your Android or iOS phone into the Google Cardboard-certified VR headset. You can then control the plane via head movements, while enjoying first-person footage streamed live via Wi-Fi from its wide-angle camera. Boasting a top speed of 32km/h (20mph), the plane features a carbon-fibre polypropylene frame and auto-stabilisation system, weighs 80g and flies for 10 minutes off a single charge.

\$200 (£165 approx), [poweruptoys.com](http://poweruptoys.com)



The plane comes complete with Google Cardboard-certified VR headset – just add a smartphone





IT'S  
GOOD TO  
TALK

## TALK TO THE ANIMALS

### TOYMAIL TALKIES

It may look like just another cuddly toy, but what you see here is actually a state-of-the-art communications system for the under-10s. Toymail made its name with cutesy devices for kids that sent and received voice messages to and from their parents' smartphones; now its latest product comes as a stuffed toy, and youngsters can use it to talk to each other as well as Mum and Dad. A Talkies app store will also let parents send songs and stories to the toys.

**\$59 (£48 approx), [toymail.co](http://toymail.co)**

## SMART SWIMWEAR

### NEVIANO UV CONNECT



This high-tech bikini features a built-in UV sensor that connects via Bluetooth to an app on your iOS or Android smartphone. Select your skin type within the app and it will send an alert to your phone whenever you've been out in the sunshine too long, thus avoiding both sunburn and the rather more serious problem of malignant melanoma. You can even have it send an alert to your partner's phone, to tell them you need some more sunscreen.

**\$142 (£116 approx), [spinali-design.com](http://spinali-design.com)**

## SPOT ON

### NVIDIA SPOT

Users of Nvidia's SHIELD Android TV set-top box will soon be able to add this \$50 microphone/speaker combo, which plugs into any available wall socket and works in a similar way to Amazon Echo and Google Home. Powered like the latter by Google Assistant, you can use it to control smart home/IoT devices, navigate YouTube, Netflix, Amazon Video, Google Play and Vudu using voice commands, search the web, order takeaway food and more.

**\$50 (£40 approx), [nvidia.com](http://nvidia.com)**

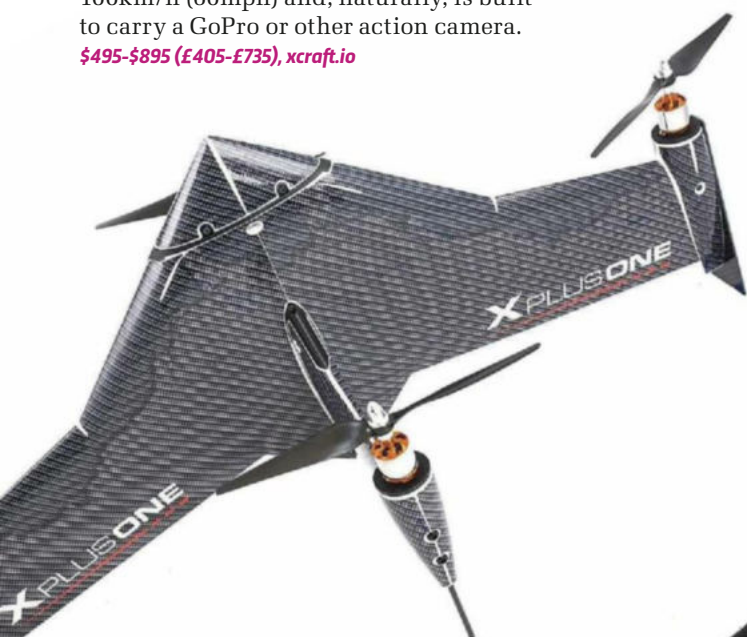


## IS IT A PLANE? NO, IT'S...

### X PLUSONE

This hybrid drone combines four sets of blades (as found on a quadcopter) with a 'flying wing' design, meaning you get the high speeds possible with the latter, combined with the vertical take-off and landing and hovering capabilities of the former. It comes with a handheld controller but can also be flown using a smartphone or tablet, has a top speed of 100km/h (60mph) and, naturally, is built to carry a GoPro or other action camera.

**\$495-\$895 (£405-£735), [xcraft.io](http://xcraft.io)**



## DUDE, WHERE'S MY CAR?

### CARIBOO

Plug this nifty little device into your car's cigarette lighter, and you'll never forget where you parked your motor again – it's linked to an iOS/Android app that'll show you exactly where you left it. It can also alert you if anyone other than yourself (or another designated driver) attempts to drive your car, can send details of your precise location to friends, and provides statistical feedback on your driving habits.

**£99 (£86 approx), [my-cariboo.com](http://my-cariboo.com)**



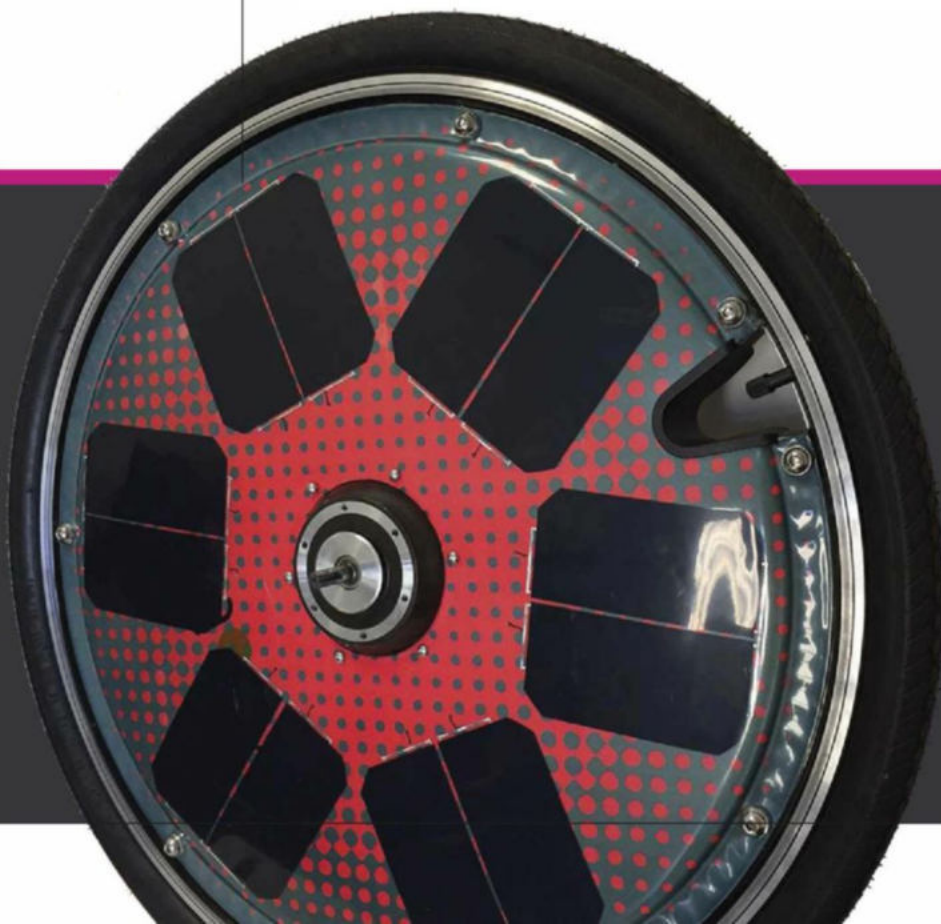
To see more of our favourite tech from CES, visit [bit.ly/FocusCES](http://bit.ly/FocusCES)

## Wheel-y clever

### ROOL'IN E-SUNNY

Electric bicycles are increasingly popular, but they're expensive. This new invention from French start-up Rool'in, on the other hand, lets you convert almost any bike into an electric one simply by changing a wheel! It's equipped with photovoltaic cells that'll provide enough electricity to power you along for up to 30km, while an accompanying smartphone lets you choose your 'assistance level' and provides data on distance travelled, average speed and so on.

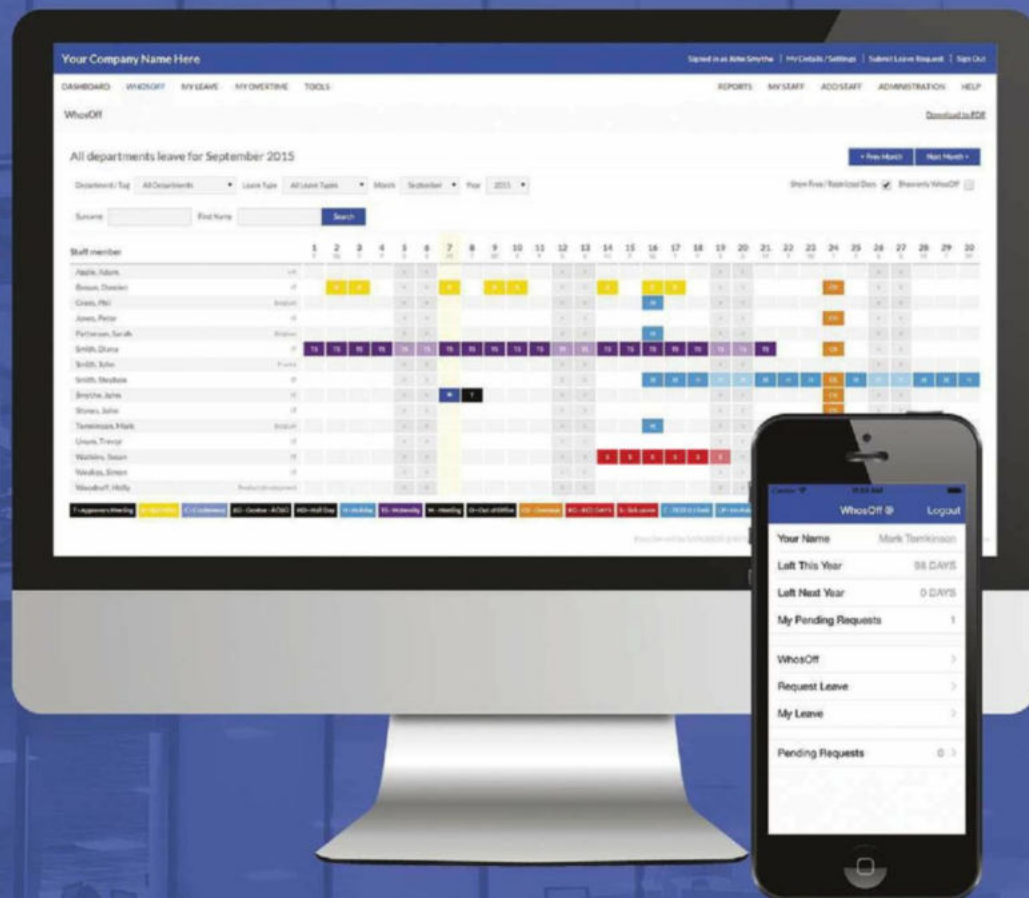
**ETBC, [rool-in.com/uk](http://rool-in.com/uk)**





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## MESSAGE OF THE MONTH

### A theory with teeth?

Regarding the mystery surrounding *T. rex*'s arms (January, p42), I was reminded that many years ago I read that *T. rex*'s missing or damaged teeth could be regularly replaced by new ones. It struck me that, if it moved its head first to one side and then to the other, its short arms could reach its mouth. Its 'hands' could then deal with the broken teeth and also tidy up any meat, sinews and bone fragments from its prey.

Miss R Wilson, Chipping Campden

➔ It's correct that dinosaurs replaced teeth throughout their lives. If they broke their teeth when eating, they could just grow new ones. But the arms of an adult *T. rex* could probably not reach the mouth and pull out any damaged chompers.

– Stephen Brusatte, palaeontologist



The mystery of *T. rex*'s tiny arms still stands...

### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Groove-e Portable Power Pack**. It can charge smartphones six times before it needs to be refuelled, and can juice up two devices at once. It even has a built-in torch – perfect for that camping trip! [groove-e.co.uk](http://groove-e.co.uk)



WORTH £60

### Babbage vs Turing? Neither!

In the January issue (p98) Robert Matthews debates who invented the computer: Charles Babbage or Alan Turing. Surely neither did. What Babbage envisaged was just an early version of machines that were subsequently built by, among others, Harold Keen at the British Tabulator Company.

What Turing envisaged was a superior version of these machines, inspired by the 'bombes' that had already been produced by the Poles. This is why Keen was tasked with turning Turing's thoughts into electromechanical reality.

Surely the real 'inventor' was the person who, when asked if he could think of any improvements to Keen's machines, abandoned the electromechanical approach and built an electronic machine from scratch, 'borrowing' parts from his employer's stores. That was the first computer and all subsequent computers can trace their lineage back to it. That person, the real inventor, was Tommy Flowers.

Robert Steel, Salisbury

➔ For all their engineering prowess, neither Keen nor Flowers can be credited with the key idea underpinning the computer: that a single machine can be programmed to perform multiple different tasks. The devices they built did not come close to the versatility envisaged by Babbage and Turing.

– Robert Matthews, science consultant

### Krispie conundrum

In the current issue (January, p67), Helen Czerski talks about the sounds that Rice Krispies make.

I went on a grand camping tour of Europe in the 1950s. I recall that in Germany the adverts stated that they made the sound 'knisper, knasper, knusper'; in France (or maybe Italy) they made the sound 'pouff, paff, poff'. But on recent trips to both Germany and France, I have not seen any adverts or even been able to buy a packet of Rice Krispies. So now what do I do?!

Richard Creak, via email

## MORE FOR YOU

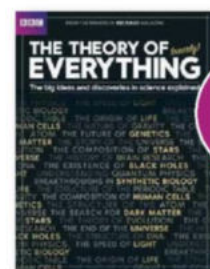
Don't forget that our magazine is also available on all major digital platforms. We have versions for Android, Kindle Fire and Kindle e-reader, as well as an iOS app for the iPad and iPhone.



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## Special issue



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# LIFE AFTER MAN

The background of the entire page is a composite image. The top half shows a clear blue sky with a large flock of birds in flight. The bottom half shows a city skyline, with the Shard skyscraper in London being a prominent feature. The city is partially covered by lush green trees and vegetation, suggesting a post-apocalyptic or 'life after man' scenario. The title 'LIFE AFTER MAN' is overlaid on the sky portion in large, white, bold, sans-serif capital letters.

**From asteroid strike to climate change to nuclear war, humanity faces all kinds of existential threats. But if our species disappeared tomorrow, what would actually happen – and what kind of planet would we be leaving behind?**

**WORDS: DUNCAN GEERE**



**W**e are living through the dawn of a new epoch in our planet's history – the Anthropocene. Humans have always shaped aspects of their environment, from fire to farming. But the influence of

*Homo sapiens* on Earth has reached such a level that it now defines current geological time.

From air pollution in the upper atmosphere to fragments of plastic at the bottom of the ocean, it's almost impossible to find a place on our planet that humankind has not touched in some way. But there's a dark cloud on the horizon. Well over 99 per cent of the species that have ever existed on Earth have died out, most during cataclysms of the sort that killed off the dinosaurs.

Humanity has never faced an event of that magnitude, but sooner or later we will.

#### THE END IS NIGH!

Human extinction, many experts believe, is not a matter of 'if', but 'when'. And some think it will come sooner rather than later. In 2010, eminent Australian virologist Frank Fenner claimed that humans will probably be extinct in the next century thanks to overpopulation, environmental destruction and climate change.

Of course, Earth can and will survive just fine without us. Life will persist, and the marks we've left on the planet will fade faster than you might think. Our cities will crumble, our fields will overgrow and our bridges will fall. "Nature will break down everything eventually," says Alan Weisman, author of the 2007 book *The World Without Us*, which examines what would happen if humans vanished from the planet. "If it can't break stuff down, it eventually buries it."

Before too long, all that will remain of humanity will be a thin layer of plastic, radioactive isotopes and chicken bones – we kill 60 billion chickens

per year – in the fossil record. For evidence of this, we can look to areas of the planet that we've been forced to vacate.

In the 19-mile exclusion zone surrounding the Chernobyl power plant in Ukraine, which was severely contaminated following the 1986 reactor meltdown, plants and animals are thriving in ways they never did before. A 2015 study funded by the Natural Environment Research Council found "abundant wildlife populations" in the zone, suggesting that humans are far more of a threat to the local flora and fauna than 30 years of chronic radiation exposure.

The speed at which nature reclaims a landscape depends a lot on the climate of an area. In the deserts of the Middle East, ruins from thousands of years ago are still visible, but the same can't be said of cities only a few hundred years old in tropical forests. In 1542, when Europeans first saw the rainforests of Brazil, they reported cities, roads and fields along the banks of major rivers. After the population was decimated by diseases that the explorers brought with them, however, these cities were quickly reclaimed by the

**"OF COURSE, EARTH CAN AND WILL SURVIVE JUST FINE WITHOUT US. LIFE WILL PERSIST"**



PHOTO: GETTY X2

## HOW COULD IT HAPPEN?

Six ways that the naked ape *Homo sapiens* could come to a sticky end



#### SYNTHETIC VIRUS

With millions of deaths chalked up to natural viruses like smallpox, influenza, HIV and Ebola, it's unsurprising that experts see an engineered virus as one of the key existential threats to humans. The first synthetic virus was created in 2002, and with the genomes of over 3,000 viruses available online, it may only be a matter of time until one is deliberately released.



#### CLIMATE CHANGE

The rate at which humans are altering Earth's atmosphere is unprecedented, and will have dire consequences unless it is slowed. As the planet heats up, vast swathes of the world will become uninhabitable, leading to mass migration and conflict. Harvests will fail and the oceans will empty of fish. With nothing to eat and nowhere to live, it's hard to see us surviving for long.



#### SUPERVOLCANO ERUPTION

The eruption of a supervolcano, like the one below Yellowstone, could pump out so much ash that it would block out the Sun, sending the Earth into an ice age and driving huge numbers of species extinct along the way. Without the Sun's energy driving almost every natural process, humans have little hope of holding on.





Just like these Roman ruins, today's buildings would still be recognisable in the future



### AI TAKEOVER

Experts estimate that we'll arrive an AI as smart as a human within the next few decades. But it won't stop there: soon the AI will be far smarter, and we'll no more be able to comprehend its thinking than a dog can comprehend ours. The likely result? Immortality, if we can keep our digital servants focused on the right goals. Or extinction, if we can't.



### NUCLEAR APOCALYPSE

The number of nuclear-armed countries is rising. Any significant exchange of nuclear weapons would have a similar effect to the eruption of a supervolcano, with ash blocking out the Sun. A nuclear winter, combined with the radioactive fallout, would result in a world where, as former Soviet leader Nikita Khrushchev once said, "the living will envy the dead".



### ANTIBIOTIC RESISTANCE

The discovery of penicillin in 1928 changed the world: an infection was no longer a death sentence but a minor inconvenience. But the overprescription of antibiotics, combined with the meat industry's fondness for routine antibiotic injections into healthy animals, has bred an increasing number of superbugs that are immune to our strongest medicines.



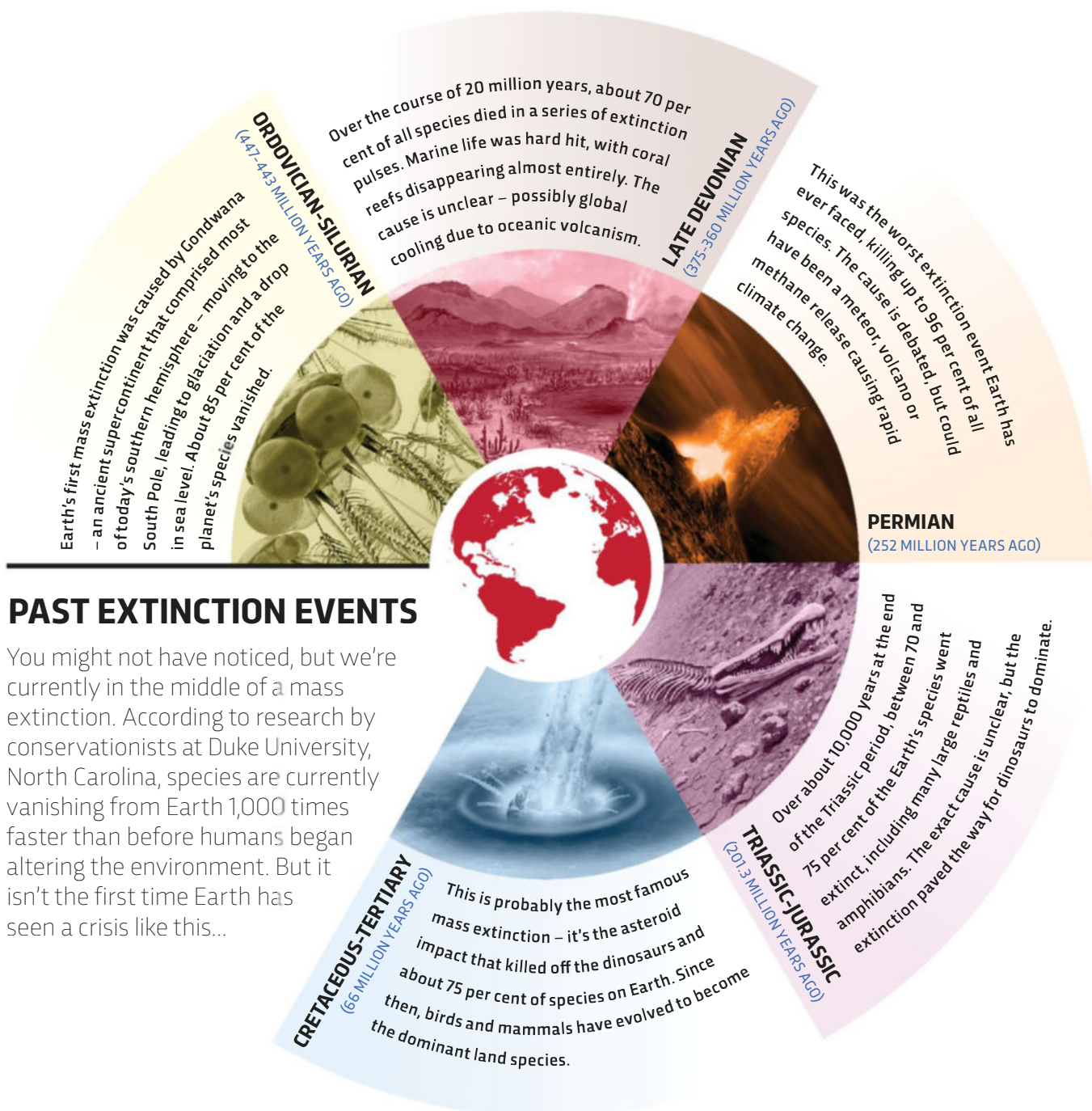


● jungle. The ruins of Las Vegas are certain to persist far longer than those of Mumbai. Only now do deforestation and remote sensing techniques offer us a glimpse of what came before.

Plant and animal species that have formed close bonds with humanity are the most likely to suffer if we disappear. The crops that feed the world, reliant as they are on regular applications of pesticides and fertilisers, would swiftly be replaced by their wild forebears. “They’re going to get outcompeted, fast,” says Weisman. “Carrots

will turn back into Queen Anne’s lace, corn may go back into teosinte – the original ear of corn that wasn’t much bigger than a sprig of wheat.”

The sudden disappearance of pesticides will also mean a population explosion for bugs. Insects are mobile, reproduce quickly and live in almost any environment, making them a highly successful class of species, even when humans are actively trying to suppress them. “They can mutate and adapt faster than anything else on the planet except for maybe microbes,” explains





Weisman. "Anything that looks delicious is going to get devoured."

The bug explosion will in turn will fuel a population increase in bug-eating species, like birds, rodents, lizards, bats and spiders, and then a boom in the species that eat those animals, and so on all the way up the food chain. But what goes up must come down – those huge populations will be unsustainable in the long term once the food that humans left behind has been consumed. The reverberations throughout the food web caused by the disappearance of humankind may still be visible as much as 100 years into the future, before things settle down into a new normal.

Some wilder breeds of cattle or sheep could survive, but most have been bred into slow and docile eating machines that will die off in huge numbers. "I think they will be very quick pickings for these feral carnivores or wild carnivores that are going to start proliferating," says Weisman. Those carnivores will include human pets, more likely cats than dogs. "I think that wolves are going to be very successful and they're going to outcompete the hell out of dogs," Weisman says. "Cats are a very successful non-native species all over the world. Everywhere they go they thrive."

The question of whether 'intelligent' life could evolve again is harder to answer. One theory holds that intelligence evolved because it helped our early ancestors survive environmental shocks. Another is that intelligence helps individuals to survive and reproduce in large social groups. A third is that intelligence is merely an indicator of healthy genes. All three scenarios could plausibly occur again in a post-human world.

"The next biggest brain in the primates per bodyweight is the baboon's, and you could say that they're the most likely candidate," says Weisman. "They live in forests but they've also learned to live on forest edges. They can gather food in savannahs really well, they know how to band together against predators. Baboons could do what we did, but on the other hand I don't see any motivation for them. Life is really good for them the way it is."

#### **POLLUTED PLANET**

The shocks that could drive baboons (or other species) out of their comfort zone could be set in motion by the disappearance of humans. Even if we all vanished tomorrow, the greenhouse gases we've pumped into the atmosphere will take tens of thousands of years to return to pre-industrial levels. Some scientists believe that we've already passed crucial tipping points – in the polar regions particularly – that will accelerate climate change even if we never emit another molecule of CO<sub>2</sub>.

Then there's the issue of the world's nuclear plants. The evidence from Chernobyl suggests that ecosystems can bounce back from radiation releases, but there are about 450 nuclear reactors

## **"SPECIES THAT HAVE CLOSE BONDS WITH HUMANITY ARE MOST LIKELY TO SUFFER"**



around the world that will start to melt down as soon as the fuel runs out in the emergency generators that supply them with coolant. There's just no way of knowing how such an enormous, abrupt release of radioactive material into the atmosphere might affect the planet's ecosystems.

And that's before we start to consider other sources of pollution. The decades following human extinction will be pockmarked by devastating oil spills, chemical leaks and ☐

Domestic cats, like these that inhabit Aoshima Island in Japan, will probably do well in a human-free world

• explosions of varying sizes – all ticking time bombs that humanity has left behind. Some of those events could lead to fires that may burn for decades. Below the town of Centralia in Pennsylvania, a seam of coal has been burning since at least 1962, forcing the evacuation of the local population and the demolition of the town. Today, the area appears as a meadow with paved streets running through it and plumes of smoke and carbon monoxide emerging from below. Nature has reclaimed the surface.

#### THE FINAL TRACES

But some traces of humankind will remain, even tens of millions of years after our end. Microbes will have time to evolve to consume the plastic we've left behind. Roads and ruins will be visible for many thousands of years (Roman concrete is still identifiable 2,000 years later) but will eventually be buried or broken up by natural forces.

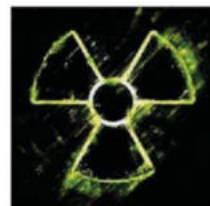
It feels reassuring that our art will be some of the last evidence that we existed. Ceramics, bronze statues and monuments like Mount Rushmore will be among our most enduring legacies. Our broadcasts, too: Earth has been transmitting its culture over electromagnetic waves for over 100 years, and those waves have passed out into space. So 100 light-years away, with a large enough antenna, you'd be able to pick up a recording of famous opera singers in New York – the first public radio broadcast, in 1910. Those waves will persist in recognisable form for a few million years, travelling further and further from Earth, until they eventually become so weak they're indistinguishable from the background noise of space.

But even radio waves will be outlived by our spacecraft. The Voyager probes, launched in 1977, are whizzing out of the Solar System at a speed of almost 60,000km/hour. As long as they don't hit anything, which is pretty unlikely (space is very empty), then they'll outlive Earth's fatal encounter with an inflating Sun in 7.5 billion years. They will be the last remaining legacy of humankind, spiralling forever out into the inky blackness of the Universe. •

**Duncan Geere** is a freelance journalist who writes about science, technology and the environment.

## 7 DAYS

Fuel runs out at the emergency generators that pump coolant into nuclear power plants. Approximately 450 reactors around the world begin to melt down.



# NO MORE HUMANS ANY MORE...

A post-apocalyptic timeline



## 2 DAYS

Without active maintenance and pumping, New York City's subways flood with water and become impassable.



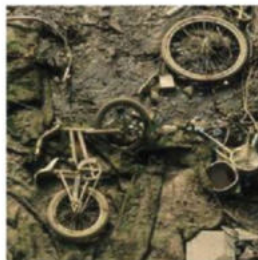
## 1 YEAR

Human head and body lice go extinct, while cockroaches in cities at temperate latitudes freeze to death. Domestic and farm animals perish in enormous numbers.



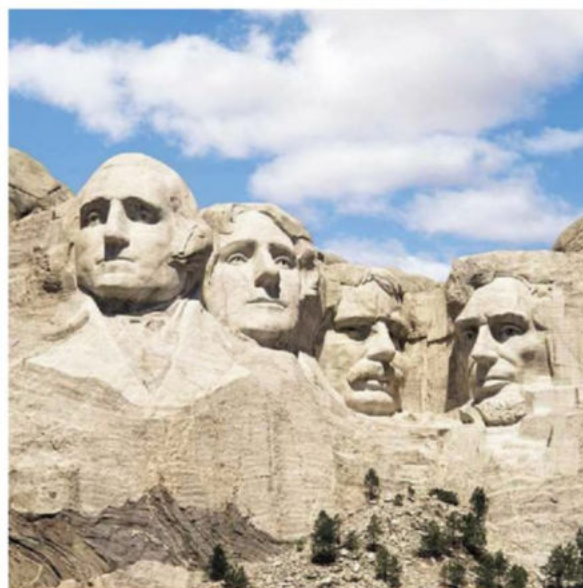
## 3 YEARS

Pipes burst in colder regions, flooding cities with water. Buildings lose structural integrity as they expand and contract with temperature changes.



## 100,000 YEARS

CO<sub>2</sub> in the atmosphere returns to pre-industrial levels. Microbes evolve to biodegrade plastic. Plutonium bombs made during the age of humans become safe to handle.



## 20 YEARS

The Panama Canal closes, rejoining North and South America. Many crops disappear, outcompeted by wild varieties.

## 300 YEARS

Most of the world's bridges fall. Dams silt up and overflow, washing away entire cities. Suburbs become forests as endangered species rebound.

## 10,000,000 YEARS

Bronze sculptures are still recognisable, as are the faces on Mount Rushmore. Life still thrives on Earth, but in new forms.



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# THE VIRUSES THAT MAD US

VIRUSES GIVE US INFECTIONS, FROM THE

COMMON COLD TO EBOLA AND AIDS.

BUT NEW RESEARCH SHOWS THAT

THEY MAY ALSO HAVE PLAYED

A KEY ROLE IN SHAPING THE

EVOLUTION OF *HOMO SAPIENS*

WORDS: KAT ARNEY



ika, Ebola, flu, even the boring old common cold – we're all familiar with the viruses that plague humanity. But while we know they make us sick, it may be surprising to discover that, over millions of years, we've managed to harness and

domesticate these crafty invaders. From the earliest stages of life to the smiles on our faces, viruses have had a huge influence on our human species.

Viruses are little more than a string of genes (usually in the form of a molecule called RNA) packaged in a protein coat, and they all work in the same basic way. Once a virus has infected a cell, it hijacks the cell's own molecular machinery to copy its genes and churn out viral proteins. New viruses are assembled from these freshly manufactured parts, which eventually burst out in search of new cells to attack [see box on p52].

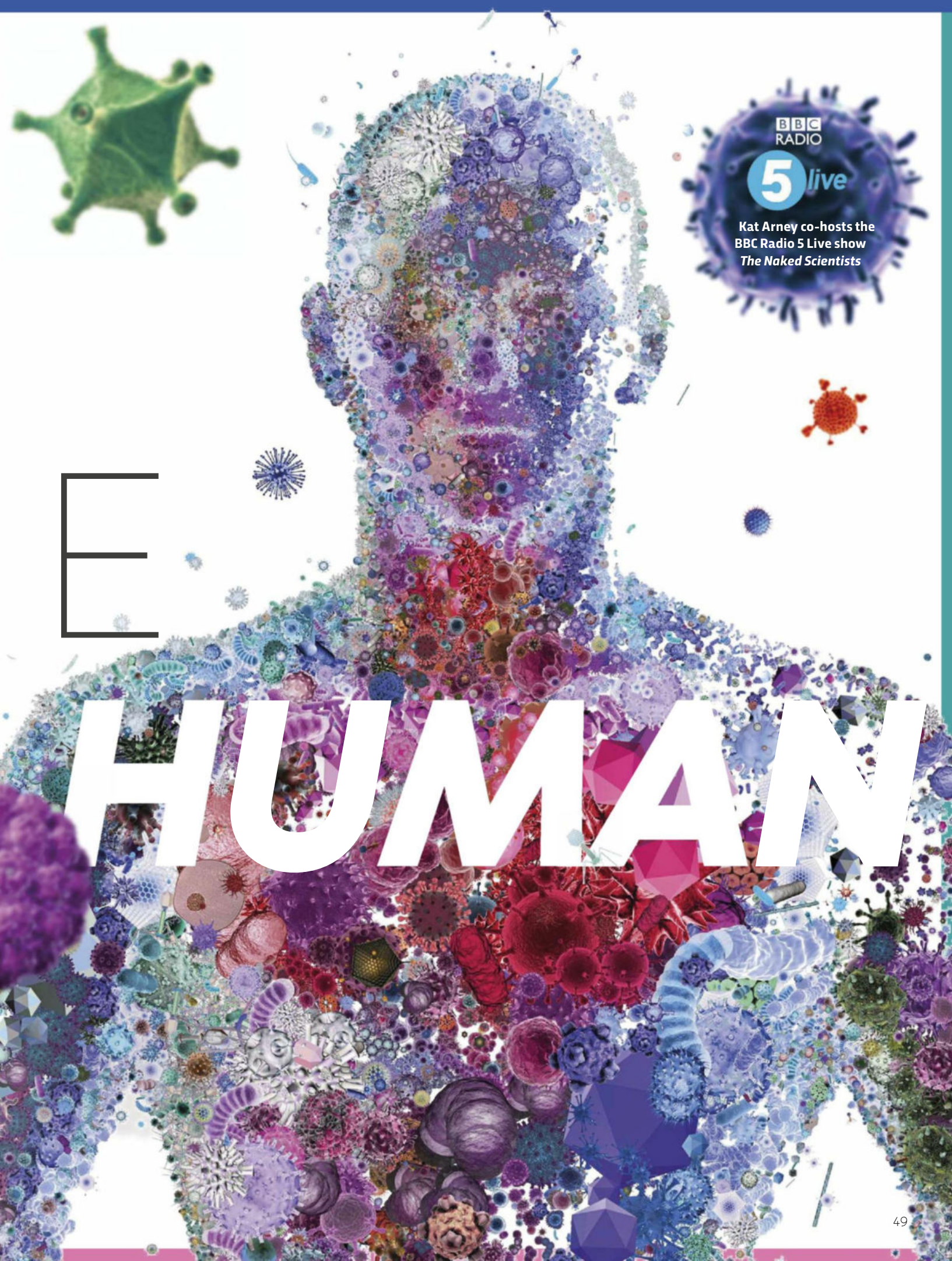
For most viruses, such as flu, the story ends there. But a handful of retroviruses – including HIV – are even

sneakier, smuggling their way into our DNA. They insert themselves randomly into the genome of an organism, lying low until the time is right to start virus production again. But once a retrovirus has got into an organism's DNA, there's no guarantee that it will stay put. The genetic instructions can be 'read' from the embedded virus, converted into DNA and then pasted into another location in the genome. Repeat this cycle again and again, and multiple copies of the viral DNA quickly build up.

Over millions of years, these viral DNA sequences randomly mutate and change, losing their ability to break free from their host cells. Trapped inside the genome, some of these 'endogenous' retroviruses can still jump around while others are stuck forever where they last landed. And if any of these events happen in the germ cells that make eggs and sperm, then they will be passed down the generations and eventually become a permanent part of an organism's genome. ●

ILLUSTRATION: CHARIS TSEVIS





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E

HUMAN



• Around half of the human genome is made up of millions of DNA sequences that can be traced back to long-dead viruses or similar ‘jumping genes’, known collectively as transposable elements or transposons. Some researchers would even put this figure up at 80 per cent, as ancient sequences are now degraded beyond the point of being recognisably virus-like, weathered within the genome like molecular fossils.

For many years, the large chunks of repetitive virus-derived DNA littering the human genome were dismissed as ‘junk’. A proportion of this repetitive stuff undoubtedly *is* little more than junk in our genetic trunk, but as researchers look more closely at individual viral elements, a more sophisticated picture is emerging. And it turns out that as well as being our genetic enemies, some of the viruses embedded in our genome have become our slaves.

#### MAKING MAMMALS

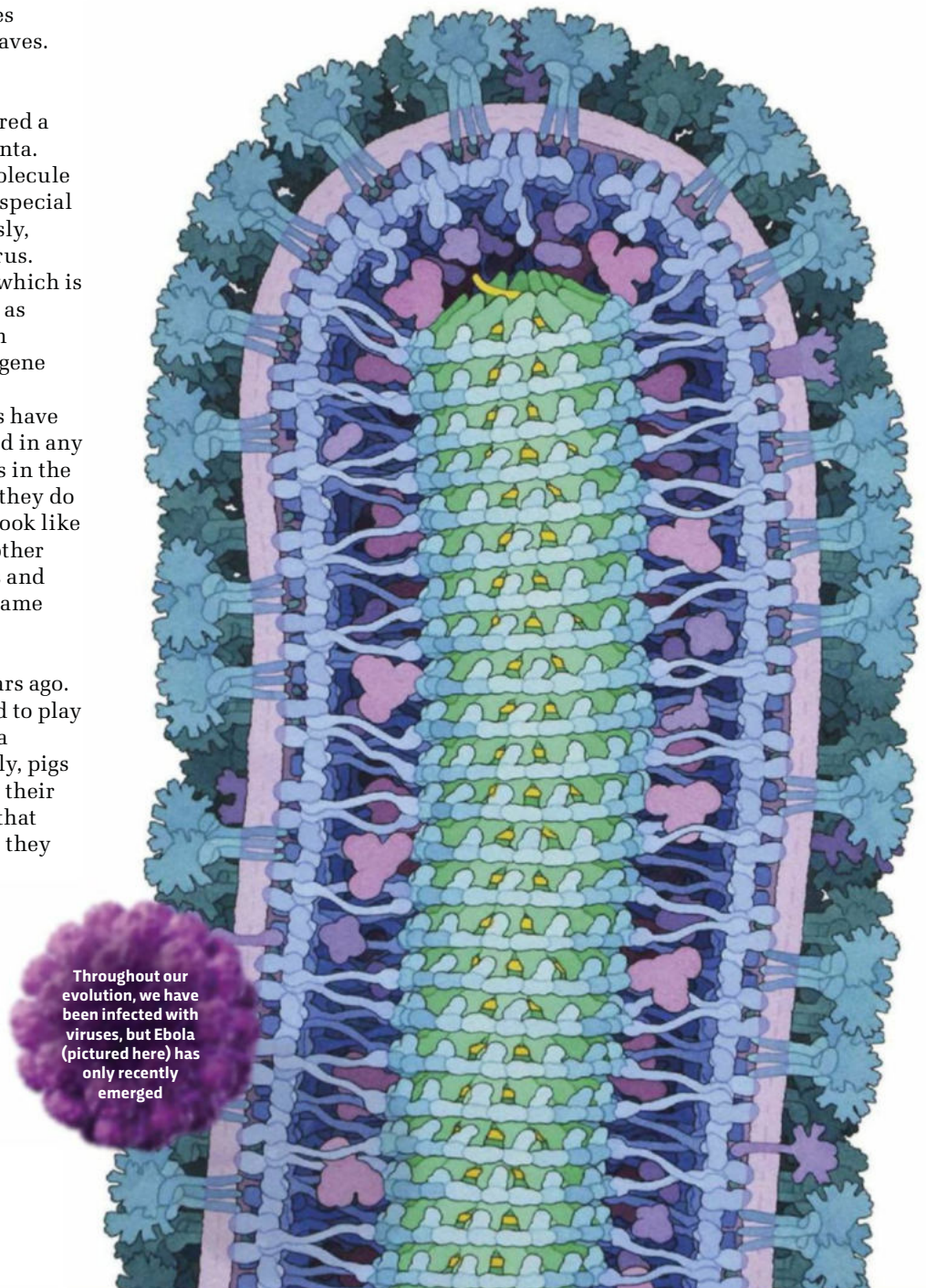
Around 15 years ago, US researchers discovered a human gene that was only active in the placenta. They called it syncytin, because it makes a molecule that fuses placental cells together, creating a special layer of tissue known as a syncytium. Curiously, syncytin looks a lot like a gene from a retrovirus. Another syncytin gene was later discovered, which is also involved in forming the placenta as well as preventing the mother’s immune system from attacking the foetus in her womb. Again, the gene looks like it has come from a retrovirus.

But while humans and other large primates have the same two syncytin genes, they aren’t found in any other mammals with similar fused cell layers in the placenta. Mice also have two syncytin genes: they do the same job as the human version, but they look like completely different viruses. And there’s another separate virally-derived syncytin gene in cats and dogs, both of which are descended from the same carnivorous ancestors.

Clearly, all these mammalian species were infected by particular viruses millions of years ago. Over time, those viruses have been harnessed to play a key role in placental growth, making them a permanent fixture in our genome. Intriguingly, pigs and horses don’t have a layer of fused cells in their placenta, and they also don’t have any genes that look like virally-derived syncitins. So maybe they never caught one of these fusing viruses.

While the case of syncytin reveals the wholesale adoption of a virus gene to do our bidding, there are many more examples of how ancient viral sequences can influence gene activity in today’s humans. Back in the 1950s, painstakingly detailed work by the long-overlooked American geneticist Barbara McClintock revealed that ‘jumping genes’ could affect the genome of maize plants. And just like the ‘jumping genes’

**“AS WELL AS BEING OUR GENETIC ENEMIES, SOME OF THE VIRUSES EMBEDDED IN OUR GENOME HAVE BECOME OUR SLAVES”**



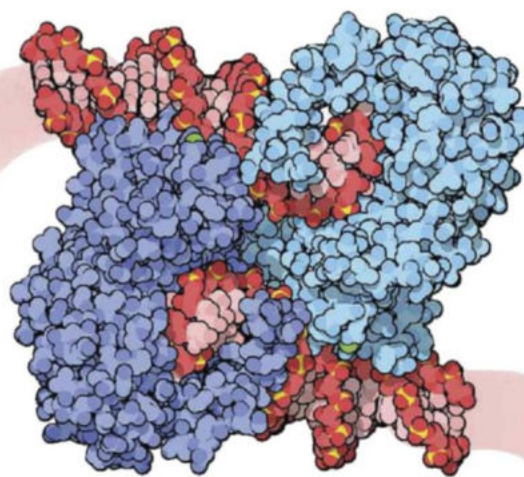


McClintock identified in maize, the endogenous retroviruses that lurk in our own human genome have been on the move over millions of years, jumping around at random and altering the activity of genes in their immediate vicinity.

Our cells invest a lot of energy in attempting to stop these viral elements from going on the hop. They're labelled and locked down with chemical tags, known as epigenetic marks. But, as the viral elements move, these molecular silencers move with them, so the viral sequences' effects can spread to neighbouring genes wherever they land.

Conversely, viruses are also full of DNA sequences that attract molecules which switch genes on. In a functional retrovirus, these 'switches' activate the viral genes so it can become infectious again. But when a virus-like sequence gets spliced into another region in the genome, this ability to act as a genetic switch can end up going rogue.

In 2016, scientists at the University of Utah found that an endogenous retrovirus in the human genome – which originally came from a virus that infected our ancestors roughly 45 million to 60 million years ago – switches on a gene called *AIM2* when it detects a molecule called interferon, which is the 'danger signal' that warns the body that it's suffering a viral infection. *AIM2* then forces the infected cells to self-destruct, to prevent the infection from spreading



ABOVE RIGHT:  
Two molecules of the 'cut and paste' enzyme transposase (blue and purple) grip onto the free ends of a DNA transposon (pink), ready to insert it into a new site within the genome

BELOW LEFT:  
Barbara McClintock first identified the effects of 'jumping genes' in maize



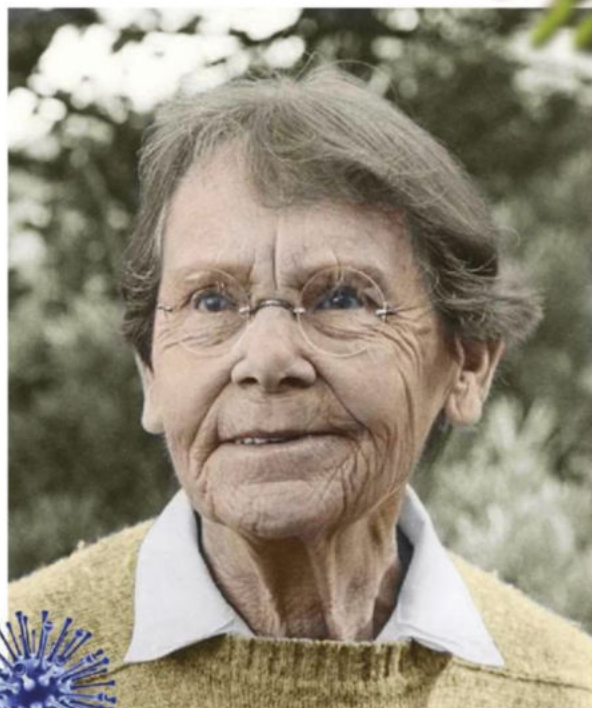
any further. These ancient viruses have become 'double agents', helping our cells to tackle other viruses that are trying to attack us.

Another example of a virus that may have shaped our species is found near a gene called *PRODH*. *PRODH* is found in our brain cells, particularly in the hippocampus. In humans, the gene is activated by a control switch made from a long-dead retrovirus. Chimpanzees also have a version of the *PRODH* gene, but it's not nearly so active in their brains. One possible explanation is that an ancient virus hopped a copy of itself next to *PRODH* in one of our long-dead ancestors, millions of years ago, but that this didn't happen in the ancestral primates that went on to evolve into today's chimps. Today, faults in *PRODH* are thought to be involved in certain brain disorders, so it's highly likely to have had at least some kind of influence on the wiring of human brains.

Similarly, variations in genetic switches are responsible for the differences between the cells that build our human faces as we grow in the womb and those of chimps. Although our genes are virtually identical to chimpanzee genes, we certainly don't look the same. So the difference must lie in the control switches. Judging by their DNA sequences, many of the switches that are active in the cells that grow our faces seem to have originally come from viruses, which must have hopped into place sometime in our evolutionary journey towards becoming the flat-faced species we are today.

#### THE VIRUS TAMERS

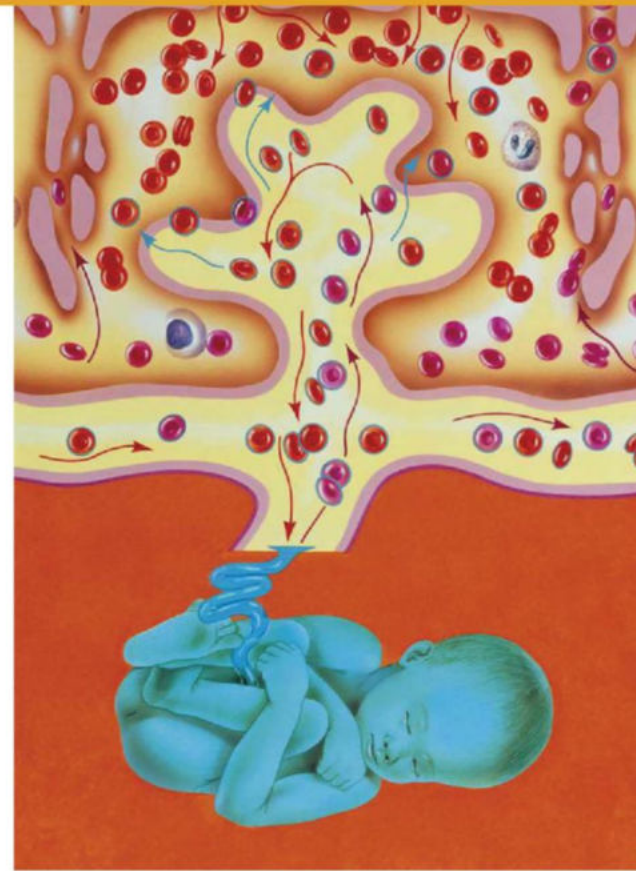
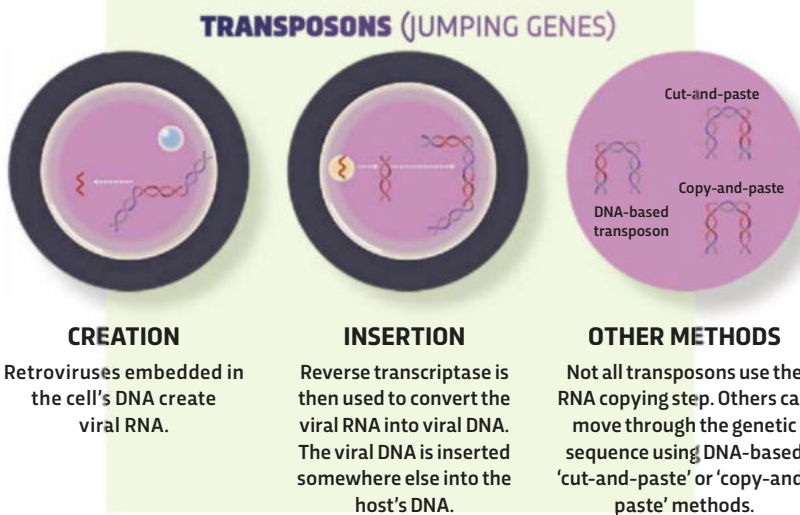
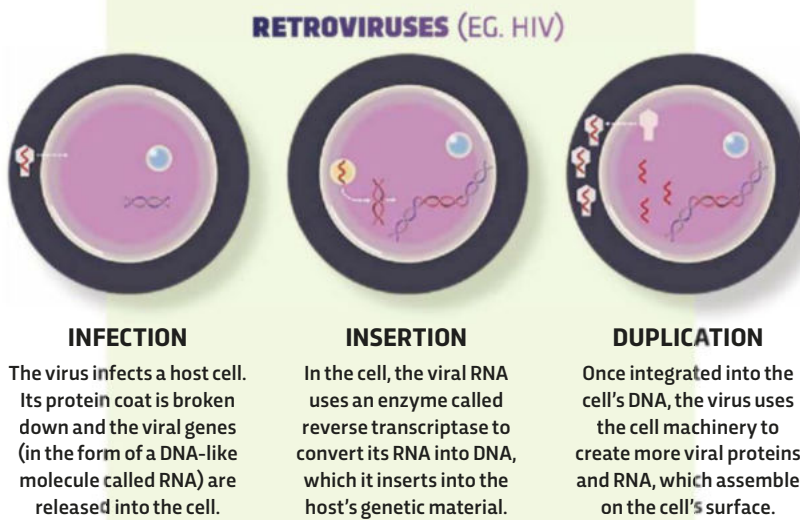
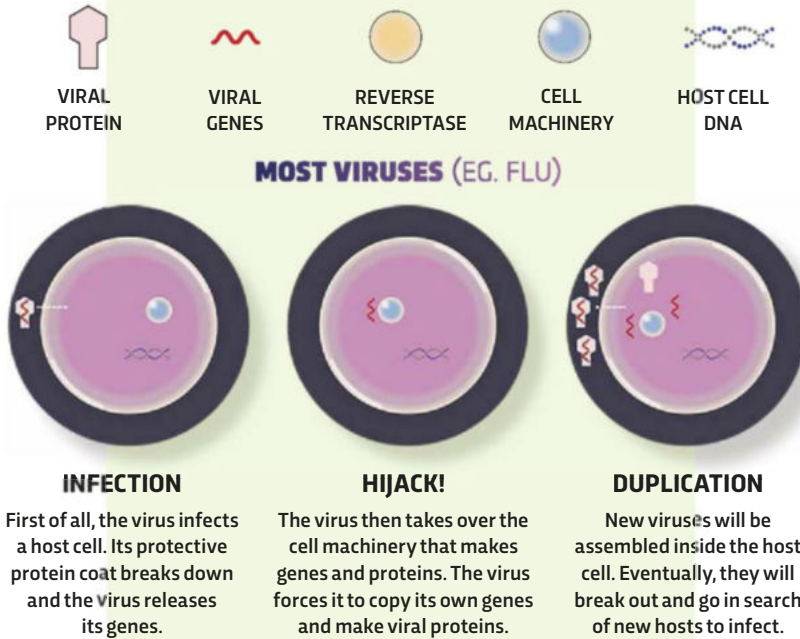
As well as searching for examples of long-dead viruses that have altered our biology, scientists are searching for the control mechanisms that



PHOTOS: DAVID S GOODSELL/RCSB PROTEIN DATA BANK X2, GETTY X2, ALAMY



## HOW VIRUSES WORK



underpin their effects. The key culprits are special silencing molecules called KRAB Zinc Finger Proteins (KRAB ZFPs), which grab hold of viral sequences in the genome and pin them in place. Prof Didier Trono and his team at the University of Lausanne in Switzerland have discovered more than 300 different KRAB ZFPs in the human genome, each of which seems to prefer a different virally-derived DNA target. Once there, they help to recruit the molecular machinery that turns genes on or off.

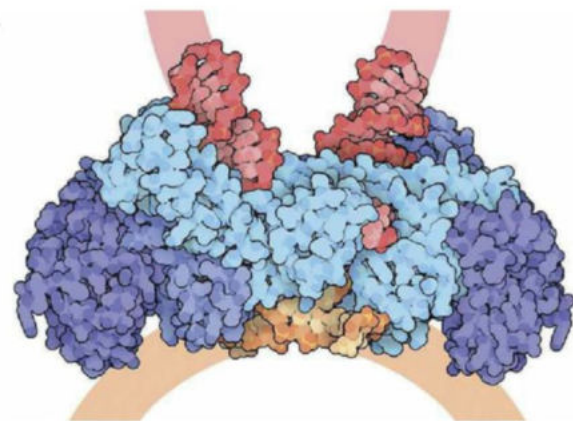
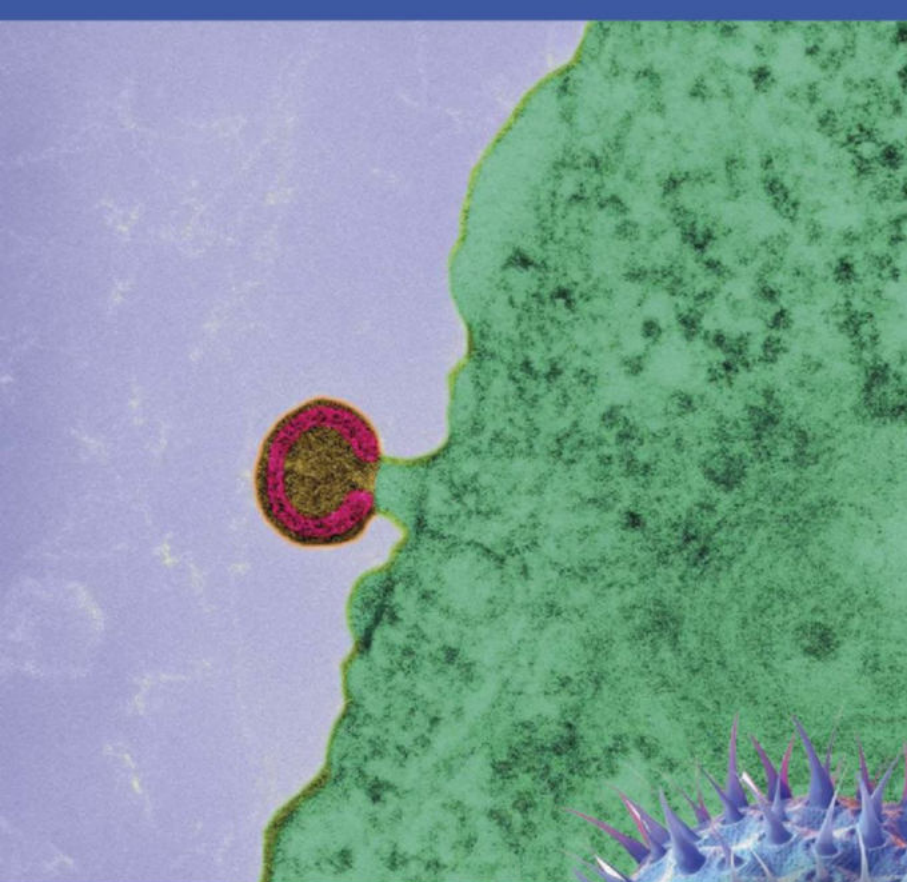
"These KRAB ZFPs have been viewed as 'killers' of these endogenous retroviruses," Trono explains. "But they are actually exploiters of these elements that allow the organism to exploit the wealth of possibility that resides in these viral sequences."

Trono and his team believe that KRAB ZFPs are the missing link between viral sequences that are actively harmful and those that have become tamed control switches. They have evidence that the proteins have evolved alongside the viral elements in a kind of 'arms race', initially suppressing them but eventually overpowering them.

"We think that what they do is domesticate these elements," Trono says. "And by domestication, I mean not just making sure that the viruses stay put, but turning them into something beneficial for the host, which is a very refined way of regulating gene activity in all possible cells and situations."

Supporting this idea is the finding that distinct groups of KRAB ZFPs are active in different types of cells. They're also found in





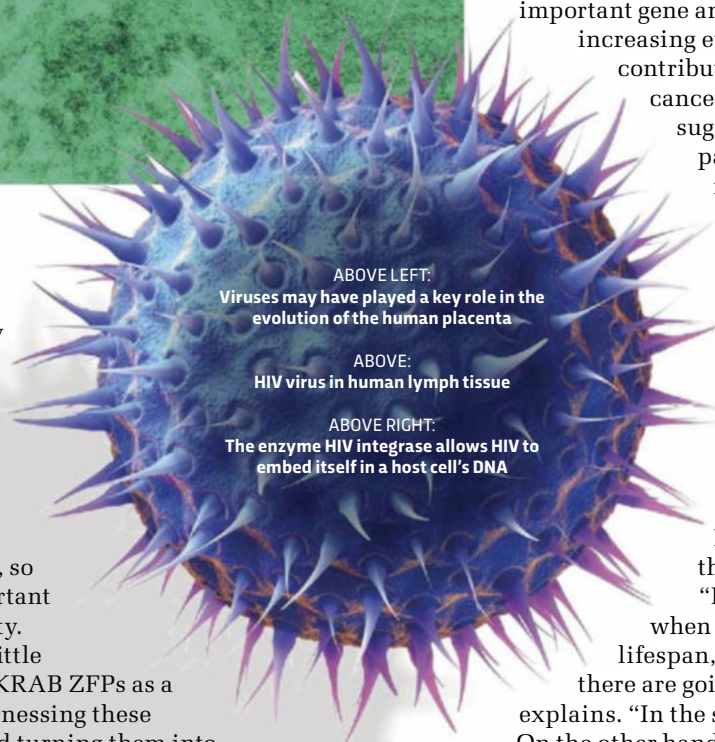
specific patterns in different species. If they were just suppressing viruses, the argument goes, the same array of proteins should be present in all cells. What's more, why would they be found bound to the many thousands of long-dead viral elements that Trono and his team have identified? There's no point suppressing a dead retrovirus, so they must be playing an important role in controlling gene activity.

Although his idea is still a little controversial, Trono sees the KRAB ZFPs as a force of viral slavedrivers, harnessing these elements to do our bidding and turning them into genetic control switches. Over many millions of years, this could have been a powerful motor for creating new species. For example, if a virus randomly goes on the hop in one ancestral creature and not another and is then tamed over time by a KRAB ZFP, it will create new control switches that could have a big impact on an animal's appearance or behaviour.

What's more, these jumping elements become more active during times of environmental change. As times get tough, species need to find new ways to adapt or they will die out. Activating these mobile elements reshuffles the genome, throwing up novel genetic variations that provide rich fodder for natural selection to work on.

#### FRIEND OR FOE?

It's clear that the viruses trapped in our genome have brought us enormous benefits on an evolutionary



ABOVE LEFT:  
Viruses may have played a key role in the evolution of the human placenta

ABOVE:  
HIV virus in human lymph tissue


ABOVE RIGHT:  
The enzyme HIV integrase allows HIV to embed itself in a host cell's DNA

timescale. But they aren't all so helpful. Around one in 20 human babies is born with a new viral 'jump' somewhere in its genome, which could deactivate an important gene and cause disease. There's

increasing evidence that jumping transposons contribute to the genetic chaos inside cancer cells. And intriguing research suggests that brain cells are particularly good locations for reactivating jumping genes, possibly increasing the diversity of nerve cells and enhancing our brainpower but also potentially causing ageing-related memory problems and conditions such as schizophrenia.

So are these viruses inside our DNA our friends or our enemies? Paolo Mita, a postdoctoral fellow researching transposons at NYU School of Medicine in New York, suggests that it's a bit of both.

"I call them our 'frenemies', because when you look at their role in one human lifespan, most likely if they are mobilised there are going to be negative effects," he explains. "In the short term, they are our enemies. On the other hand, if you are looking across time, these elements are a powerful force of evolution and they are still active in our species today. Evolution is just the way that organisms respond to changes in the environment, and in this case they are definitely our friends because they have shaped how our genome works now."

And are the viruses infecting us today, such as HIV, going to have an impact on our evolution in the future? "Of course! The answer is why not?" laughs Mita. "But it will be many generations until we can look back and say this evolution has happened. But you can see the remnants of previous arms races in the genome between the endogenous retroviruses and the host cells. It's a continuous battle, and I don't think it has ever stopped." 

**Kat Arney** is a science writer and broadcaster. She hosts BBC Radio 5 Live's *The Naked Scientists* and is the author of *Herding Hemingway's Cats: Understanding How Our Genes Work*.

# ***CAN YOU SUPERCHARGE YOUR BRAIN?***



Your brain is the finely tuned machine that controls all your actions and emotions, so it makes sense to keep it well-oiled. But are there any scientifically proven methods to ensure it works better for longer?

WORDS: RITA CARTER



## PROTECTION

Absolutely the best thing you can do to preserve your brain is to protect it from injury. This may sound obvious, but the long-term effects of brain trauma are only just being recognised.

According to Headway, the brain injury charity, about one million people in the UK currently live with memory loss, confusion and psychosis due to brain injuries that may have happened years before. People with a history of brain injuries suffer earlier cognitive decline and succumb to dementia earlier than others, and – scarily – they are at least three times as likely as others to go to prison.

Falls, sports-related incidents and road accidents are the main causes of head injury. So the first, simplest thing you can do for your brain is to wear sensible shoes and a protective helmet when you are cycling or doing any kind of sport where there's a chance of getting your head bashed.

***“About one million people in the UK live with memory loss, confusion, and psychosis due to brain injuries that may have happened years before”***



Protecting your brain from injury is probably the most important step you can take

## NUTRITION

The second thing you can do is to protect your brain from internal injury – and that means eating properly.

The brain is a famously hungry organ, using about one-fifth of the body's calorific intake. Brain food is delivered by the blood via a dense mesh of vessels. If the blood hits a bottleneck it may form a clot, causing a stroke. Depending on its

size and location, a stroke may deal a catastrophic blow, or pass by barely noticed. Such minor strokes are called Transient Ischemic Attacks (TIAs), but while they might not cause much problem when they happen, repeated TIAs cause severe cognitive decline. Vascular dementia (as such a decline is known) is almost as common as Alzheimer's disease.



### HELP PREVENT STROKE BY ADDING THESE FOODS TO YOUR DIET:



**Antioxidants**, which clean up the detritus left by normal metabolic processes. Dark-coloured foods such as blueberries, dark chocolate, kidney beans and artichokes are brimming with antioxidants.



**Vitamins A, B, C, D and E**, which between them help clean away rubbish, strengthen arteries and keep brain cells healthy. Find them in wholegrain cereals, eggs, chicken, nuts and leafy greens.



**Omega-3 and other non-saturated oils**, which strengthen and clean the arteries as well as helping to build brain cell membranes. Good sources of omega-3 include oily fish, walnuts and edible seeds.



**Neurotransmitter precursors** such as tryptophan and glucosinolates. Find them in milk, nuts, seeds, tofu, cheese, red meat, chicken, turkey, fish, oats, beans, lentils, eggs and broccoli.

## SUPPLEMENTS

A varied diet should provide all the brain-healthy nutrients you need, but could you benefit from taking more of them? Here the answers get much less certain.

Omega-3 is the supplement best known as a brain booster. It is the type of oil found in fatty fish like herrings, sardines and mackerel. The literature on oils and the brain would sink a tanker, but most of it is based on small, commercially motivated or otherwise unreliable studies. When these are removed, the evidence that's left is underwhelming. A 2012 review by the Cochrane organisation – widely acknowledged as the ultimate authority on health – found no evidence that omega-3 reduces the risk of cognitive impairment, while a 2015 meta-analysis by Canadian scientists concluded bluntly: "Omega-3 fatty acids, B vitamins, and vitamin E supplementation did not affect cognition in non-demented middle-aged and older adults."

Similarly, evidence for herbal supplements ginseng and ginkgo biloba fails to stand up to strict scrutiny, as does that for practically every other 'brain-booster'. The Natural Medicines Comprehensive Database, a non-commercial organisation which continuously collects and reviews data, failed to find a single proven effective supplement among more than 50 they assessed. They rated a few as "possibly effective" but most simply had "insufficient evidence" to call.

Lack of proof of efficacy is not, however, proof of lack of efficacy. The large-scale, expensive research needed to show beyond doubt if a thing works or not is usually done only for medicinal drugs, so it's not surprising that there isn't any to show what works for healthy people.

Supplements are not without risk – they can interfere with medicines and produce nasty side effects, especially if too many are taken. However, a supplement which gives the recommended daily dose of required vitamins and minerals may be a good idea if you feel your brain needs a boost, especially if you think your diet may be deficient in any way.

***"Evidence for herbal supplements fails to stand up to scrutiny"***

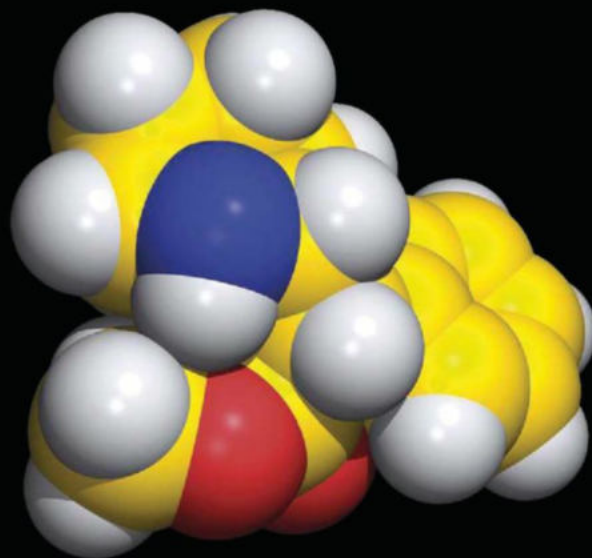
Found in oily fish, omega-3 is often touted as being beneficial for the brain, but the evidence for this is surprisingly weak



## DRUGS

### RITALIN ►

Famous for its use in treating children with Attention Deficit Hyperactivity Disorder (ADHD), Ritalin and its derivatives also seem to help concentration and focus in adults with the condition. It probably does something for healthy people too, but – guess what? – the evidence isn't there to prove it.



### ◀ ANTIDEPRESSANTS

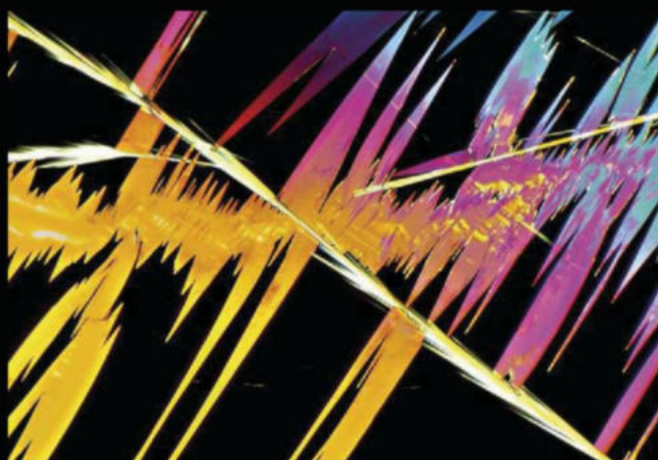
Depression is not just a mood disorder, it has profound effects on cognition generally – blurring memory, slowing thought and distorting perception. Most antidepressants, when they work, bring these things back to normal and a few – Bupropion, Prozac, reboxetine and SNRIs (serotonin-norepinephrine-reuptake inhibitors) – may make people brighter than normal, even if they are not depressed. However, antidepressants also tend to have side effects, so unless you actually *are* depressed, taking them probably isn't a great idea.

### ANTI-INFLAMMATORIES ►

Inflammation, the process by which body cells go on the attack, is increasingly implicated in brain-based conditions such as depression, memory loss and behavioural disorders.

Alzheimer's disease may also be due to inflammation, at least in part. Evidence is accumulating that the amyloid plaques associated with the disease are not themselves its cause; rather, it is the brain's inflammatory reaction to the plaques that kills off brain cells. This probably explains why low-dose aspirin – famous for its anti-inflammatory properties – seems to stave off cognitive decline (as well as heart attacks and many forms of cancer).

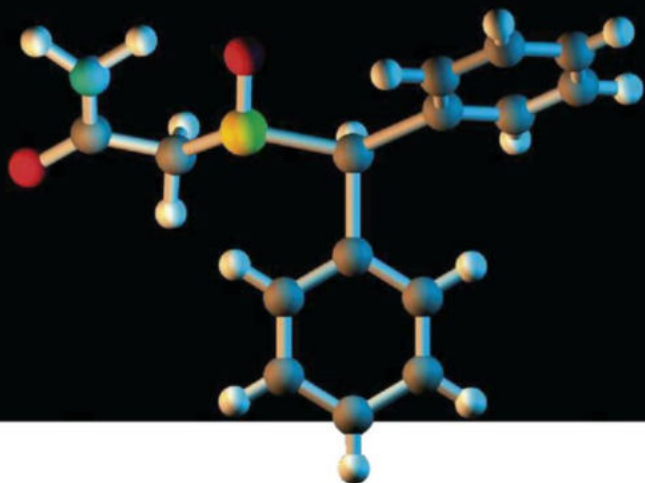
Aspirin is not recommended for healthy people by medical authorities, but current evidence makes a low-dose daily aspirin pill a rational choice.



### ◀ PRESCRIPTION DRUGS

Modafinil is a prescription drug used to treat narcolepsy, but it's looking as though it might be a general brain sharpener. Researchers at Oxford University and Harvard Medical School (where up to a quarter of students report taking the drug to help their work) reviewed 24 studies of Modafinil and concluded that it improves thinking skills and helps with planning, decision-making, flexibility, learning, memory and creativity, with very little downside.

Prof Guy Goodwin, president of the European College of Neuropsychopharmacology (ECNP), said: "It seems to be the first real example of a 'smart drug', which can genuinely help, for example, with exam preparation."



## LEARN A LANGUAGE OR INSTRUMENT

So far only two types of mental exertion have been shown to improve or preserve overall cognitive ability. One is musical training; the other is learning a new language, or practising a second one you have already learned.

Gottfried Schlaug, director of the Music and Neuroimaging Laboratory at Harvard University explains: "Listening to and making music is not only an auditory experience; it's a multisensory and motor experience. Playing an instrument changes how the brain interprets and integrates a wide range of sensory information, and making music over a long period of time can change brain function and brain structure"

As for the role of language-learning in boosting brain power, a team at Edinburgh University assessed mental alertness in a group of 33 students (aged 18-78) who undertook a one-week Scottish Gaelic course. After the course they were encouraged to practise their new language for five hours a week. At the end of the course, their attention was found to be better than comparison groups who had done other types of courses or no course at all, and nine months later those who had been practising had bumped up their attention span even more.

Lead researcher, Dr Thomas Bak of the School of Philosophy, Psychology and Language Sciences said the results confirm the cognitive benefits of language-learning. "I think there are three important messages from our study: firstly, it is never too late to start a novel mental activity such as learning a new language. Secondly, even a short, intensive course can show beneficial effects on some cognitive functions. Thirdly, this effect can be maintained through practice."

**"Even a short, intensive course can show benefits on some cognitive functions"**



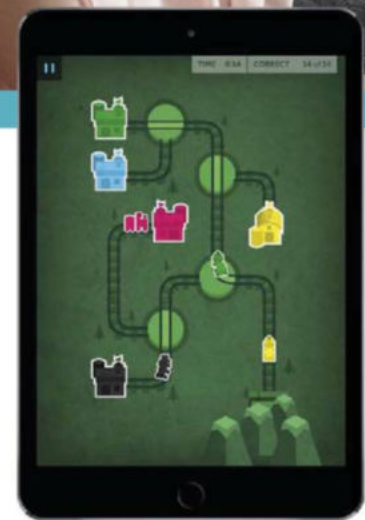
## BRAIN TRAINING

Any mental exercise helps cognition by building, lengthening or strengthening the pathways that carry information between neurons. Generally, the more pathways you have, the better your cognition.

When you carry out a particular mental skill, connective tissue builds up in the part of the brain responsible for it, just like arm exercises build your biceps. For all-round cognitive improvement, therefore, you should do lots of everything: motor skills (ie, physical activity), talking, socialising, planning, game-playing,

calculating, writing, reading and talking. But the problem is that we tend *not* to do everything, especially as we get older.

This is where brain training comes in. Systems like Lumosity, Brain HQ and SmartMind claim to exercise all parts of your brain, and thus to raise your cognitive abilities generally, rather than in one particular area. Alas, the proof of this is just not there. Scientists reviewed the literature that brain-training companies cite to support their products and found that, while people got better at individual tests, there was no general improvement in cognition.



Brain-training apps only improve the brain's performance at particular tasks



## ELECTRICAL STIMULATION

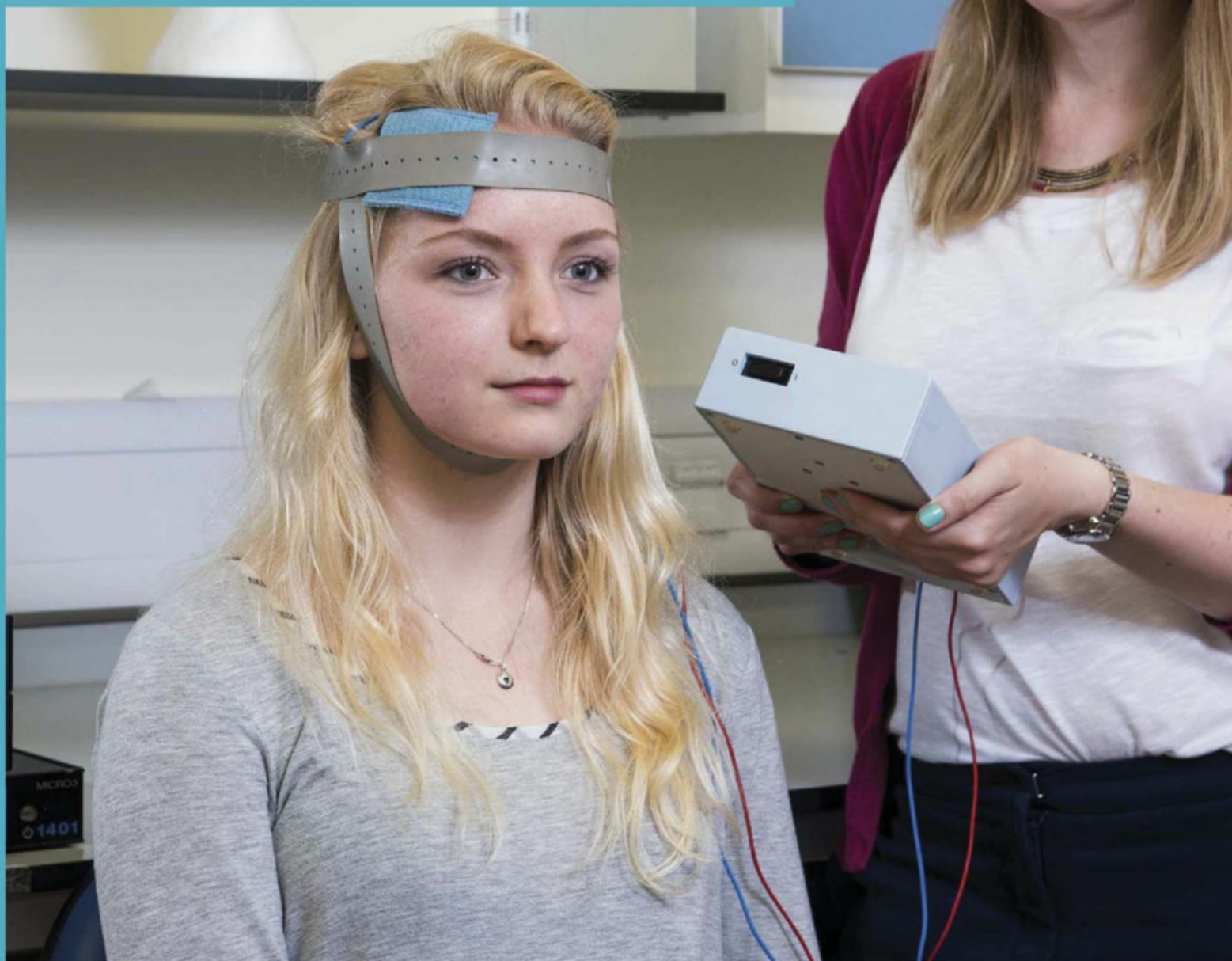
Devices that send a weak electrical current through your brain via head-mounted electrodes are marketed online as cognitive enhancers. Transcranial Direct Current Stimulation (tDCS) – not to be confused with Transcranial Magnetic Stimulation (TMS) – is claimed by those who sell it to speed up reactions, calm you down, help you focus, increase physical endurance and improve more or less any mental skill you want.

Although it sounds gimmicky, there is actually a vast amount of solid evidential support for tDCS both as a treatment (for

pain, depression, tinnitus, dementia and much else) and for enhancement. When it's used correctly it is extraordinarily safe, and comparatively cheap – you can get a tDCS kit for about £100.

However, like brain training, tDCS has not yet shown itself capable of improving overall cognition (rather than individual functions), and much of what's known about it has come from a large, dedicated band of DIY researchers, and as a result is anecdotal and/or difficult to assess. Judge the evidence for yourself at [reddit.com/r/tDCS/](https://www.reddit.com/r/tDCS/).

**Rita Carter** is a science writer, lecturer and broadcaster, specialising in the brain.



Devices that use tDCS (transcranial Direct Current Stimulation) to 'boost your brain' are widely available, though scientific evidence that they do so is hard to find

# SHOULD WE BE WORRIED ABOUT AN ASTEROID HITTING EARTH?

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*Four years after Russia's Chelyabinsk impact, we take a look  
at whether space rocks are as scary as they seem...*

WORDS: STUART CLARK

**T**he day of 15 February 2013 was a day like no other, and one I will never forget. Potentially hazardous asteroids were firmly on my mind because that evening the space rock 2012 DA14 was due to make an incredibly close pass of our planet. It measured about 45m across (half a football pitch) and was going to zip by Earth 10 times closer than the Moon.

There was no danger of it hitting the Earth – its orbit was well known. Nonetheless it was a timely reminder of the perils of the Solar System's asteroid population. I had written an article about 2012 DA14 that was attracting a fair amount of readers on *The Guardian's* website.

Then I got an early morning phone call from one of the newspaper's editors. People were reporting that a meteorite had hit Russia. Could the orbit prediction have been wrong and the asteroid arrived early?

I began calling astronomers and searching the internet immediately. The first YouTube video I saw had been taken on a shaky phone and showed some streets and a loud bang, followed by a view of a thick vapour trail in the sky. I found a few more and then I started to come across the dashcam views of the meteor streaking across the sky. Either this was an elaborate hoax or...

I hardly dared believe it was real but the astronomers I talked to were coming to realise that something truly had struck Earth. It couldn't possibly be 2012 DA14. It had to be a wholly unrelated, totally unexpected impact.

The editor phoned back; the foreign desk had confirmed that people had been injured in the Chelyabinsk region of Russia by the falling ☛





## “Asteroids capable of destroying whole countries will be lurking undetected”

● object. A pit opened in my stomach. As the day's event's unfolded and I did my best to report them, I realised just how frightening and real the threat from asteroids is.

In the final analysis, the Chelyabinsk impactor had been just 20m in diameter and carried around 12,500 tonnes. It had exploded about 30km above the ground and the shock wave this created had damaged more than 7,000 buildings in six cities across the region. Most seriously, around 1,500 people had received medical assistance for their injuries, the majority of which were caused by broken glass from windows shattered by the blast. The only consolation was that no one had died.

At 20m wide, the Chelyabinsk impactor was a minnow in asteroid terms. An impactor measuring 100m across would destroy a city. Moving up the size scale, the devastation grows to the size of small countries or states. If the asteroid is greater than a kilometre in size, then the effects start to reach around the globe. This is because of the amount of dust blown into the atmosphere. Rather like the hypothesised nuclear winter, the dust blocks out the Sun and the climate suffers. Wide-scale fires are also ignited by the incandescent debris falling back to Earth. The curtains really close at diameters of 10km and more. These are the impactors that cause mass extinction events, global conflagrations and long-term climate change.

### ASTEROID ANALYSIS

Fascination with doom from the skies is by no means a morbid modern concern. For centuries, there has been a lot of talk about such catastrophes. Edmond Halley, who famously calculated the elliptical trajectories of comets in the late 17th Century, remarked at the biblical destruction that a collision with one of these celestial wanderers could bring.

The modern interest, however, gained momentum in 1980 when a small team of researchers led by father and son Luis and Walter Alvarez



Edmond Halley observed the transit of Solar System bodies, allowing him to compute the orbit of what is now known as Halley's Comet



presented evidence that a layer of iridium could be found in rocks from all across the world. The layer was dated to approximately 66 million years ago, which coincides with the Cretaceous-Paleogene (previously known as the Cretaceous-Tertiary) mass extinction which put paid to the last of the dinosaurs.

The importance of the iridium is that although it is extremely rare in Earth's crust, it is abundant in asteroids. Its presence suggested that a giant asteroid impact triggered the dying off of many species, or at least delivered the coup de grace. Since that time, there has been a lot of talk, many surveys and a great deal of academic studies. In 2000, Tony Blair's government created a three-man task force to provide an official document about the risk of asteroid strikes. Chaired by Harry Atkinson, a former chairman of the European Space Agency's (ESA) Council, the report it produced went a long way to having the threat recognised as a real one.

PHOTO: GETTY X2





Since then, much progress has been made. In the US, Congress mandated NASA to detect potentially hazardous asteroids. By 2009, NASA experts were confident they had detected 90 per cent of near-Earth asteroids larger than a kilometre in diameter. Their goal is currently to do the same for asteroids down to 140m in diameter by 2020. Even if they manage to achieve that goal, it still means that asteroids capable of destroying whole countries will be lurking out there undetected.

#### PROTECT THE PLANET

The conclusion is inescapable: to safeguard Earth we need a way of deflecting any incoming asteroids that we do discover. There are a number of methods that have been proposed to nudge asteroids out of the way, but the best way is to smash something into them to alter their orbit.

That's where the joint NASA-ESA mission AIDA (Asteroid Impact & Deflection Assessment)

Researchers Luis and Walter Alvarez, seen here studying a star dome, established that an asteroid may have smashed into Earth at the end of the Cretaceous Period

comes in. AIDA consists of two spacecraft. The first is ESA's AIM (Asteroid Impact Mission). The second is NASA's DART (Double Asteroid Redirection Test).

Launching in October 2020, AIM would journey to Didymos. This asteroid was discovered in 1996, but what makes it special is that it is composed of two parts. The main body is 800m across and it is circled by a 'moon' that is just 150m across, making it a perfect target for a deflection test.

AIM would position itself close to the asteroid to remotely analyse it using its onboard instruments. Then, in 2022, NASA's part of the mission would arrive. DART would target the moon, rather affectionately called 'didymoon', and collide with it at high velocity. AIM would then study the moon to see what changes had occurred to its structure and orbit.

It would be the first test of deflecting an asteroid. But there is a significant hitch. ●



ABOVE: The DART probe is due to arrive at the asteroid Didymos in 2022

RIGHT: The shock wave from the Chelyabinsk impactor caused extensive damage

After a detailed study performed by the European Space Agency, the plans for the mission were presented to European science ministers at the ESA ministerial conference in December 2016. Although the first day's negotiation looked promising with many countries wanting to buy into the programme, the key country was Germany. For the mission to proceed, it needed to grant €60m but Germany only had €35m left to play with. Although other countries stepped in to take up some of the slack, it wasn't enough.

Ultimately, Germany then withdrew their €35m pledge, leaving ESA with no alternative but to stop work on the programme. Writing about the decision, ESA's director general Jan Wörner stated, "Ultimately – and this I very much regret – the difficult discussions among member states and a focus on direct applications and short-term return led inevitably to a situation in which I had no choice but to announce the proposal's cancellation."

This is not the first time that ESA has been in this situation. About a decade ago, I stepped off a

plane in Paris and caught a taxi to ESA's headquarters. I was working at the time with the ESA Advanced Concepts Team and had been invited to hear their deliberations for a mission called Don Quijote. This was a two-part space mission that would have attempted to divert 2004 MN4, a 400m-wide asteroid. After deliberating, the politicians decided not to fund that beyond the study phase.

Now AIM has gone the same way. So what gives? No one doubts that the devastation an incoming asteroid could cause is colossal. But some politicians still cannot see the benefit of protecting against this threat. The worst part is that at around €200m, AIM was a low-cost space mission. In comparison, ESA's Rosetta comet mission, which concluded in September 2016, cost upwards of €1bn.



### RAISING AWARENESS

Less than a week after ESA's withdrawal from AIDA, the United Nations announced that "The United Nations Office for Outer Space Affairs is pleased to announce that the United Nations General Assembly has proclaimed that International Asteroid Day will be observed globally on 30 June every year."

This date is the anniversary of the Tunguska event. On 30 June 1908, an asteroid measuring around 100m in diameter exploded about 5-10 kilometres above the uninhabited Tunguska region of Siberia. The enormous blast released as much energy as 1,000 Hiroshima nuclear bombs and flattened a 2,000km<sup>2</sup> area of forest.

As a private endeavour, Asteroid Day has run for the last two years. I've been a supporter since the very beginning. I remember founder Grig Richters phoning me one afternoon as I was leaving work and asking whether I thought a concert like Live Aid could work for raising the awareness of asteroids. Sure, I said, why not? In the event, Richters didn't exactly get a rock concert, but he did get a rock star to back the venture. Dr Brian May has proved to be an eloquent, influential, and informed supporter of the cause. ●

PHOTO: ESA, PRESS ASSOCIATION X2

**"No one doubts that the devastation an incoming asteroid could cause is colossal"**



During the Chelyabinsk event, Lake Chebarkul was hit by a major meteor fragment, which smashed a huge hole through the icy surface



● I chaired the main Asteroid Day event in 2014. It was a panel discussion at London's Science Museum, and one of the participants was Astronomer Royal Martin Rees. His numbers stuck in my mind. By calculating the risk from asteroids in the same way that insurance companies set their premiums, he worked out that globally we should be spending \$1bn a year on protecting ourselves from trouble. The actual figure that gets spent by space agencies (mostly NASA) is in the tens of millions of dollars. We are lagging far behind the curve on this one.

Yet, it's not all doom and gloom. NASA will still go ahead with their part of the AIDA mission. And ESA's Wörner claims that he is exploring other possible ways of funding the European segment. But he will have to hurry if the 2020 launch is to remain a possibility.

And now that the UN has taken Richter's Asteroid Day under its auspices, we can but hope that its message will be amplified and reach the politicians. Space missions are a boost to the economy – remember, someone has to build the

spacecraft. The technology and effort needed translates into jobs and saleable expertise.

To me, it should be a no-brainer that we work on building up our deflection capabilities. Admittedly asteroid strikes are rare but as Chelyabinsk proved, they can strike out of nowhere. We may not have the luxury of decades to prepare a defence when danger is spotted. We should be getting ready to deploy countermeasures at any time.

So, should we worry about an asteroid hitting Earth? No, so long as we prepare. But as the recent ESA ministerial meeting demonstrates, politicians are sticking their heads in the sand because they prefer to “focus on direct applications and short-term return”. This is the real worry: the short-sighted introspection that is currently endemic in the political system. ●

BELOW:  
Eminent  
scientists at an  
Asteroid Day  
event. From  
left to right:  
Lewis Dartnell,  
Alan  
Fitzsimmons,  
Brian May,  
Stuart Clark  
and Martin  
Rees

**Dr Stuart Clark** (@DrStuClark) is an astronomy writer and author of *The Search For Earth's Twin* (£20, Quercus Books). [stuartclark.com](http://stuartclark.com)

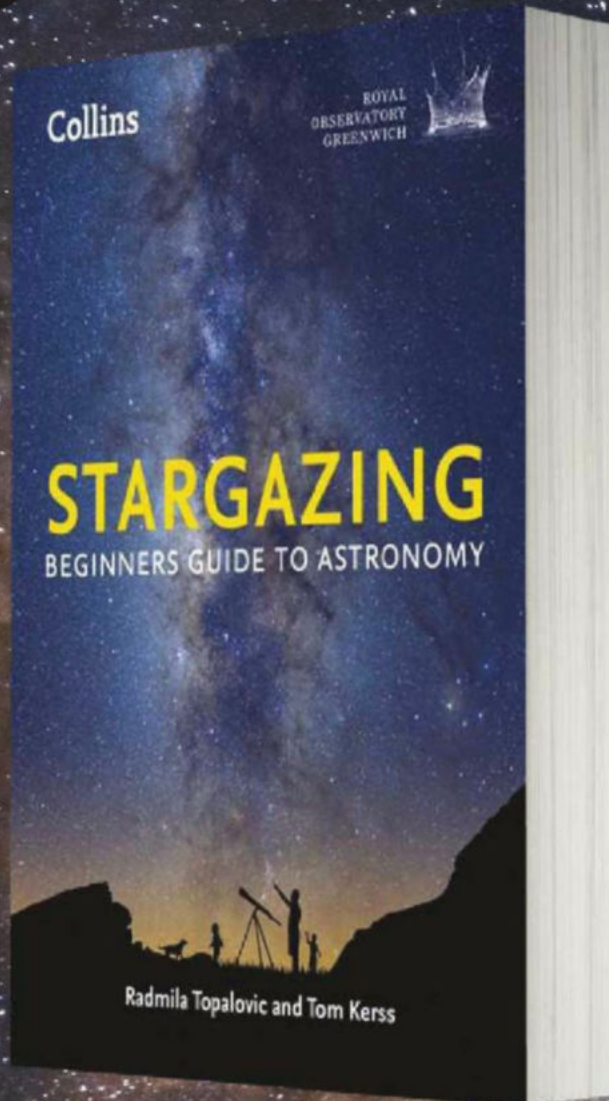
PHOTO: GRIGORI RICHTERS/ASTEROID DAY



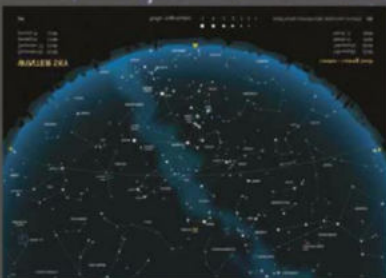


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## CORE ISSUES

There is no way for us to dig down to the Earth's core to take a peep at what's inside – it's just too far away (and too hot!). Instead, researchers have to use seismometers and clever measurements to establish the composition of our planet's interior.





# HOW DO WE KNOW...

## WHAT'S AT THE CENTRE OF THE EARTH?

We live on the surface of a dense, rocky ball, but science has allowed us to peer deep within its core

WORDS: BRIAN CLEGG

When the pioneering science fiction writer Jules Verne wrote *Journey To The Centre Of The Earth* in 1864, he probably knew that his plot was pure fantasy. Verne's characters Otto, Axel and their guide Hans, only made it a few miles down, but the idea that anyone could even contemplate travelling to the Earth's core had been dismissed before Victorian times.

Even today, the furthest we've ever drilled into the Earth is around 12km, while the distance to the centre is over 500 times further, at 6,370km. So how do we know what lies beneath? Figuring out what's at the heart of our planet has been a magnificent scientific puzzle.

### Living on a ball

The idea of the Earth having a meaningful centre goes hand-in-hand with the planet being shaped like a ball, and we've known that we don't live on a disc for a long time. It's a myth that medieval folk thought the Earth was flat – this actually came from a mix of Victorian anti-religious propaganda, and a misinterpretation of the stylised maps of the period. It was over 2,200 years ago that the Greek polymath Eratosthenes made the first measurement of the distance around the Earth's sphere, and it's

been clear ever since that it must have a centre.

This doesn't mean, though, that early philosophers thought of Earth as we do today. Ancient Greek physics said that the world consisted of a series of concentric spheres of four fundamental elements: earth, water, air and, finally, fire. In this oldest scientific picture, the centre of the planet had to be solid, as air couldn't be inside the sphere of earth. Clearly, the sphere of earth wasn't completely

surrounded by water or there'd be no dry land, so there was thought to be a bit of the earth sticking out – meaning there could only be one continent. As a result, the discovery of the Americas was one of the first experimental scientific results, disproving the idea of a single continent, and marking a significant step on the way to disposing of Ancient Greek science.

The idea of the Earth being entirely hollow, or with vast caverns reaching to the centre as in Verne's book, has



Misinterpreted maps from the medieval period led to the myth that people once thought the Earth was flat

Danish seismologist  
Inge Lehmann  
established that our  
planet has a solid core



• been popular in fiction and mythology since ancient times, also featuring in various pseudoscientific and conspiracy theories. However, it's not clear that any scientist apart from the astronomer Edmond Halley, who proposed a hollow Earth to explain some unusual compass readings in 1692, has ever taken this idea seriously. And in 1798, an English scientist and eccentric put the final nail in the coffin of the 'hollow Earth' hypothesis. This was when Henry Cavendish weighed the planet.

### Weighing the planet

Cavendish was an odd man, who only communicated with his servants via notes to avoid meeting them face-to-face. Despite his aristocratic background, Cavendish dedicated his life to science, working in both chemistry and physics, and most famously devised an experiment to calculate the density of the Earth.

Using a simple torsion balance, which measured the amount of twisting force caused by the gravitational pull of two large balls on a smaller pair, Cavendish was able to calculate the faint gravitational attraction between the two pairs of balls. By comparing this with the Earth's own gravitational pull, he could work out the planet's density (and, as the Earth's size was already known, its mass, too). But the density

figure showed that our planet must be mostly solid, unless there were extremely dense unknown materials somewhere in the depths.

Today, we split the innards of the Earth into three segments: the crust, which is the outer layer, between 5km and 75km thick, the mantle, extending to a depth of around 2,900km, and the core – the bit we're interested in here – extending around 3,500km out from the Earth's centre, with two distinct segments. At the core's heart is an extremely hot but still solid nickel-iron sphere with a radius of around 1,200km. At approximately 5,400°C, this inner core is similar in temperature to the surface of the Sun. The remainder is the liquid outer core, also mostly nickel-iron, with similar temperatures, getting hotter towards the centre. But how can we possibly know such detail about a location that is so inaccessible?

Given the near-impossibility of ever getting even within a thousand kilometres of the core, all our knowledge is indirect and depends on seismology – the science of earthquakes. After a quake, seismic waves travel through the Earth, changing their form and direction depending on the materials they pass through. Geophysicists have used this information to deduce what lies at the Earth's core. Their seismometers, devices to measure such waves, are •



Charles Richter confirmed Inge Lehmann's theory that the Earth had a solid core; he also created the Richter Scale to define the magnitude of earthquakes

## GLOSSARY

### Longitudinal waves

These waves consist of a series of compressions and relaxations in the direction of travel, like a slinky spring given a push along its length. Examples include sound and P-waves.



### Refraction

When a wave hits the boundary between two materials, travelling at an angle, it changes direction. Light waves, for instance, are refracted when passing between water and air, making a straight object appear bent.



### Seismology

The study of earthquakes. Analysis of how different types of seismic wave travel through the Earth has allowed us to piece together our planet's inner structure.



### Torsion balance

This apparatus consists of a bar, suspended from a frame by a twisty fibre. As the bar moves sideways, it applies a force to the fibre – the further it twists, the greater the force.



### Transverse waves

These waves consist of a series of side-to-side vibrations, like the waves sent through a rope by moving one end up and down. Examples include light and S-waves.



# TIMELINE: UNDERSTANDING THE EARTH'S CORE

Scientists managed to find out what is at the centre of our planet, without ever picking up a spade...

1798



## HENRY CAVENDISH (1731-1810)

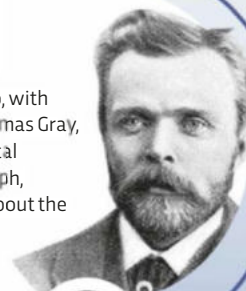
This English scientist used a torsion balance to measure the gravitational attraction between heavy balls, deducing Earth's density.

1798

Henry Cavendish publishes the results of his experiment that gives the first figure for the density of the planet. This figure proves sufficiently high that it is very unlikely that the Earth is hollow.

## JOHN MILNE (1850-1913)

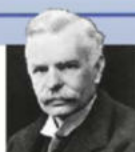
English geologist who, with James Ewing and Thomas Gray, invented the horizontal pendulum seismograph, making discoveries about the core possible.



1936

1936

Inge Lehmann interprets the P-waves in the shadow zone as reflections from a solid inner core within the liquid core of the Earth, completing our modern understanding of the Earth's structure.



## RICHARD DIXON OLDHAM (1858-1936)

Dublin-born geologist who identified the main wave types on seismograph recordings. He deduced that the Earth had a liquid core and made an approximation of its size.

1906

1906

Richard Oldham, in retirement, makes use of the data on arrival times of seismic waves at different points on the Earth's surface to deduce that planet Earth has a liquid core.

1938



1938

Beno Gutenberg and Charles Richter (pictured) confirm Lehmann's theory, working backwards from the idea of a solid core to see what size would produce the timings used by Lehmann.

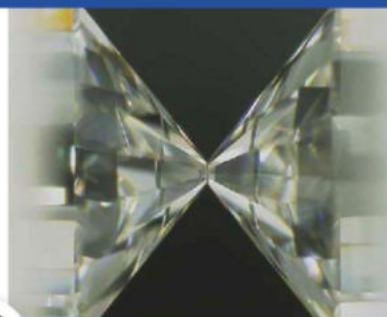
## INGE LEHMANN (1888-1993)

Despite her breakthrough identification of the structure of the Earth's core, notably after the 1929 New Zealand earthquake, Lehmann, a Danish seismologist and geophysicist, was never awarded a professorship.



## KEI HIROSE (1968-)

Hirose is a professor of earth and planetary sciences at Tokyo Institute of Technology. He is a leading researcher into the Earth's deep interior, simulating the core by using diamond anvil cells.



2011

Kei Hirose and his team make the best attempt to recreate conditions at the Earth's core, putting nickel-iron alloy under extreme pressure and raising it to 4,500°C.

2011



Earth's internal structure: upper mantle (red), lower mantle (orange), outer core (yellow), and inner core (grey)

## THE KEY DISCOVERY

**Scientist:** Inge Lehmann

**Date:** 1929 to 1936

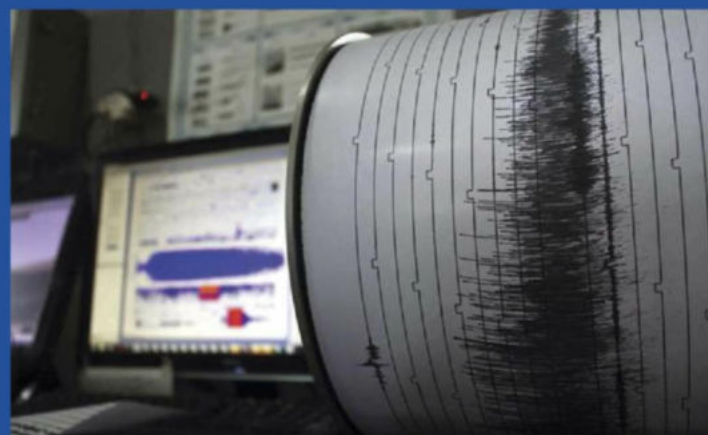
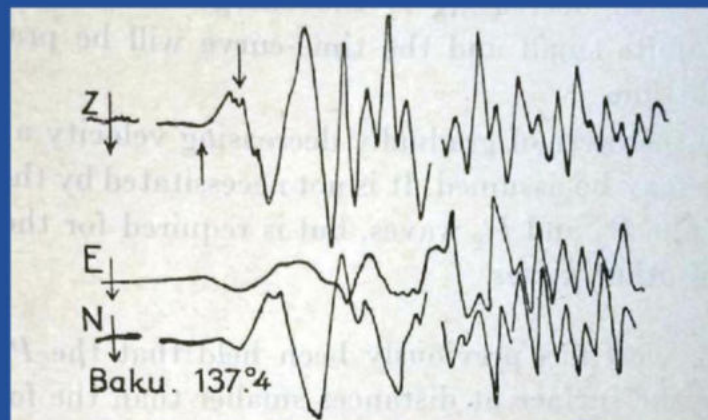
**Discovery:** Earth has a solid inner core

On 17 June 1929, at around 10:17am local time, a 7.3-magnitude earthquake struck the South Island of New Zealand. Waves from the quake were recorded on seismometers around the world, notably in Frankfurt, Copenhagen, Baku, Sverdlovsk and Irkutsk. These devices consisted of a heavy weight, suspended from a frame. When the Earth and the frame vibrated, the inertia of the weight prevented it from moving with them, creating a difference in motion that could be captured by a pen on a rolling sheet of paper.

The first accurate seismometers responded to up and down movements in a horizontal arm, but shortly before the New Zealand

earthquake, a new kind of seismometer using a vertically suspended weight came into play, and these proved crucial in the discovery.

Danish seismologist Inge Lehmann had been working for a couple of years comparing the output of seismic stations. Initially working with published data, and then going to the original records as "published readings were not always satisfactory", Lehmann discovered oddities in the wave patterns. She realised that seismic waves arriving between around  $104^\circ$  and  $140^\circ$  from the epicentre had interacted with a solid inner core, disproving the previously accepted belief that the Earth's core was entirely liquid.



TOP: Lehmann investigated seismometer recordings of an earthquake in 1929, and found that some of the waves must have interacted with a solid core

BOTTOM: Modern seismometer showing activity during a volcanic eruption

the equivalent of telescopes for exploring the **Earth's interior**.

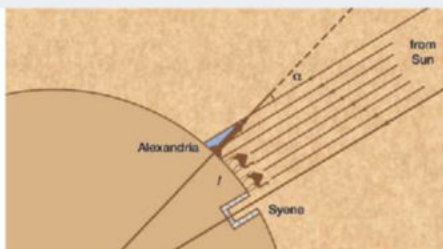
By the early 20th Century, the increasing temperatures as we dug deeper into the Earth, combined with seismologists' analysis of earthly waves, suggested that the inner parts of our planet were at least partly molten – hot enough to turn rock and metal into liquid. And the key discoveries were made by two scientists who, shamefully, were never even nominated for a Nobel Prize: British geologist Richard Oldham and Danish seismologist Inge Lehmann.

### Wonderful waves

Think of a wave, and you'll probably think of a surface wave, like one you'd see on the sea. But many waves – sound, for example – travel through the body of a material. Though the seismic waves that cause damage in an earthquake are those that travel on the surface, there are also two types of 'body wave' that move through the Earth. P-waves ('P' stands for 'primary') are longitudinal waves, just like sound. They vibrate in the direction of movement, causing the Earth to squash up and expand as they pass through. P-waves travel rapidly – around 5km per second in a rock like granite, and up to 14km per second in the densest parts of the mantle. The second type of body wave, S-waves ('S' stands for 'secondary'), are slower, transverse waves, moving from side-to-side. Unlike P-waves, they can't travel through a liquid, which is why these two types of wave proved essential in helping us understand the Earth's core.

Imagine there's a huge earthquake. Waves begin to move through the Earth. The P-waves shoot ahead, while the S-waves follow behind at around half the speed. Both types of wave will be detected by seismometers, which are used to measure vibrations in the ground, all over the Earth. But where the waves pass through the core to reach a distant measuring station, there is a so-called shadow zone. Travel about  $104^\circ$  around the Earth's perimeter from the quake's epicentre





Eratosthenes' knowledge of the Sun and given locations on the planet helped him calculate Earth's circumference

and the waves disappear. But from 140° onwards, the P-waves reappear, with no accompanying S-waves.

As early as 1906, Richard Oldham realised the implications of this odd shadow. Oldham spent most of his career with the Geological Survey of India, often working in the Himalayas. When he retired to the UK in 1903, he made use of the data accumulated over the previous few years to probe the interior of the Earth. He realised that the observed P-wave and S-wave behaviour could be explained if the centre of the Earth was liquid. In such a case, P-waves would be refracted by the liquid, bending as light does when it moves from water to air, leaving a distinctive shadow. S-waves, by contrast, would be stopped entirely by a liquid core.

Oldham's breakthrough led to a widely accepted picture of a molten core, but 30 years later, Inge Lehmann realised that Oldham's idea was too simple. The refraction of the P-waves by the dense liquid in the centre of the Earth should have produced a total shadow. However, measurements made with the more sensitive seismometers available by Lehmann's time showed that faint P-waves were still arriving in the shadow zone. By studying data passing through the planet from a 1929 New Zealand earthquake (see 'The key discovery'),

Lehmann proposed that these waves were being reflected off the boundary between an inner solid core and the outer liquid. Her results, published in 1936, were confirmed two years later by Beno Gutenberg and Charles Richter, who accurately modelled the effects of a solid core. Direct measurements of these reflected seismic waves finally came in 1970.

### Under pressure

Further studies picked up even more subtle waves which, from their delayed arrival, had to have crossed the liquid outer core as P-waves, before being converted to transverse S-waves in the inner core, and then back to P-waves on the way out. This discovery, only confirmed in 2005, was further proof of the solid core.

Even so, the exact nature of the inner core is subject to significant debate. Temperatures, for instance, can only be worked out from experimental studies of how materials melt and solidify under pressure. And the assumption that the core consists primarily of iron and nickel comes from a combination of the frequency with which different elements occur in our local region of the Milky Way, and our understanding of how our planet formed.

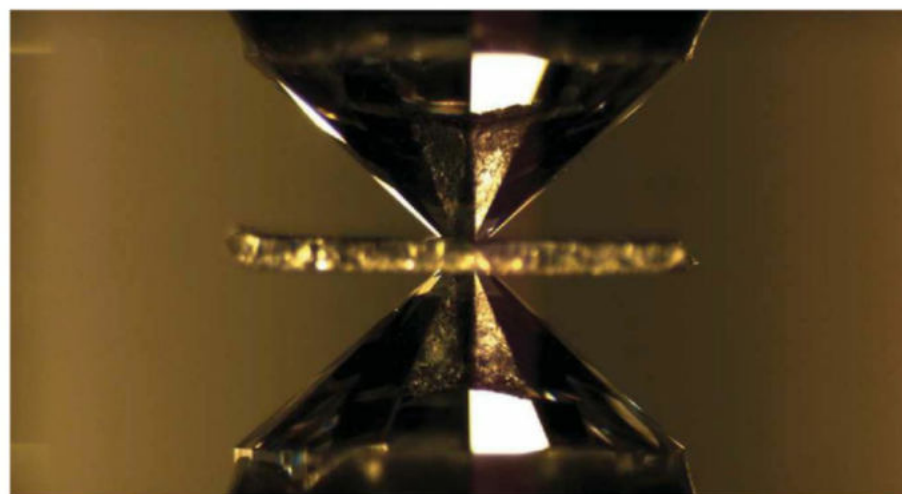
Under the immense pressure at the centre of the Earth – over three million

times atmospheric pressure – materials can act very differently from normal conditions. While the most obvious contender for the inner core is a solid nickel-iron alloy, it is possible for an extremely dense plasma – the state of matter found in a star – to have similar properties. One of the difficulties here is knowing how materials behave in such extreme environments.

Enter the diamond anvil cell. In this remarkable device, the points of two diamonds, just a fraction of a millimetre across, are squeezed together. Applying a force to a small area produces more pressure than applying it to a wide one – that's why being trodden on by a stiletto heel is much more painful than a flat sole. The diamond anvil creates pressures up to twice that of the Earth's core, and heating is applied using lasers. When metallic samples are crushed and heated to core-like conditions, the results suggest a crystalline solid in the centre of the Earth.

Realistically, we will never get anywhere near the Earth's core. The levels of heat, pressure and radioactivity (one of the main sources of internal heating) are so high that even if we could bore through over 6,000km of rock and metal, a probe would be unable to survive. Compared with reaching the core, travelling to the outer reaches of the Solar System is trivial. But our planet's own vibrations, produced by earthquakes and interpreted by scientists as ingenious as Inge Lehmann, give us the means to explore with our minds where we will never visit in person. 🌐

In a diamond anvil cell, metals are squished between two diamonds at enormous pressures, to simulate conditions at the Earth's core



Brian Clegg is a prolific science writer. His most recent book is *Are Numbers Real?* (£12.99, Robinson).

#### DISCOVER MORE



Listen to an episode of *In Our Time* about the Earth's core at [bbc.in/1zdcaKF](http://bbc.in/1zdcaKF)

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## HELEN CZERSKI... WHAT CAUSES PLANE TRAILS?

**“WHY WERE PLANES LEAVING WHITE RIBBONS ON ONE DAY WHEN THEY HADN’T ON THE PREVIOUS DAYS?”**

**A**

t the time of writing this column, there have been several beautifully clear days, which have been cold and frosty at ground level with stunningly blue skies above. But on one of those days, the bright, clear sky was decorated with criss-

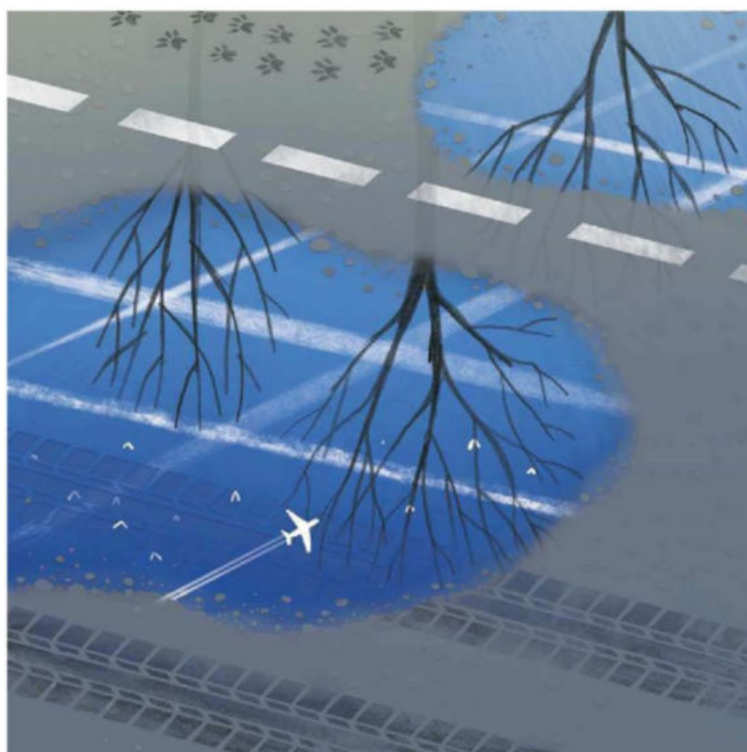
crossing white lines: contrails from aircraft. For me, wandering along by the river at ground level, the conditions on that day seemed exactly the same as the previous ones. So what had changed up in the atmosphere? Why were aircraft leaving these elegant white ribbons on one day when they hadn’t on the previous days?

The conditions in which the aircraft fly are harsh and unforgiving. Cruising altitude is about 10km, where each cubic metre of air has only a third as many molecules as what we breathe at ground level, and the temperature hovers around -50°C.

The engines take in air because they need oxygen to burn their fuel. A jet engine exhaust is a stream of hot gas, made mostly of the products of combustion, carbon dioxide and water (it’s easy to forget about the water, with all the concern about CO<sub>2</sub> these days). There are also tiny particles of soot, and these are where a contrail is really born.

As the hot exhaust gases from the plane hit the thin and frigid air, they cool extremely rapidly. The water molecules are bouncing around as a gas, but if they hit a speck of soot, they’re likely to condense onto it to make a drop of liquid. So each soot particle becomes a starting point for a liquid water droplet. This is the contribution of the jet engine itself. What happens next depends on the air around the plane.

At such low pressures, the water molecules could quite easily evaporate again, drifting away as an invisible gas. But if the air around the plane already has lots of water in it – if it’s humid – then the liquid drops will start to grow because there are plenty of water molecules bumping into the drop that might stick. Within a fraction of a second of coming out of the engine, each droplet will freeze into a tiny ice crystal. This is what we’re looking at when we see contrails – billions of fragile ice crystals, each one perhaps only one-hundredth of a millimetre across. The majority of the contrail is made of water from the



surrounding air, not the exhaust – any nearby water can condense onto the soot.

There might only be a few hundred ice crystals in each cubic centimetre of air, but a typical mature contrail is perhaps 6km wide and 1km thick. They’re gigantic! But then they’d have to be, for us to see them from the ground. On the coldest, most humid days, these trails of ice crystals can stretch for hundreds of kilometres across the sky. As long as the air surrounding them is still cold and humid enough, there’s no reason for them to change, so they just sit there. Sometimes the largest crystals (usually near the edges) will start to settle out, and you’ll see streaks as the crystals drift downward.

So on that particular day, the contrails were telling me that 10km up in the sky, the air happened to be really humid.

I find it frustrating that I can’t see the subtlety of our atmosphere more often – how sad that it’s almost all invisible! But at least once in a while, a plane can offer a glimpse into that hidden world. **Q**

**Dr Helen Czerski** is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, is out now (£8.99, Transworld).

**NEXT ISSUE: PULSING OF LED LIGHTS**

**free their potential – teach**



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Biologist,  
geneticist



**PROF ROBERT MATTHEWS**  
Physicist,  
science writer

# YOUR QUESTIONS ANSWERED

FEBRUARY 2017

EDITED BY EMMA BAYLEY

## How many UK spiders are actually dangerous?

JULIA REYNOLDS, MILTON KEYNES

Essentially, none. There are three common spiders in the UK that are capable of biting you: the cellar spider, the woodlouse spider and the false widow spider. Their bites are painful and have been known to cause swelling for a few hours. In 2014 a 60-year-old woman died after being bitten by a false widow spider. However, the cause of death was due to a bacterial infection from the puncture wound, rather than the spider venom itself. **LV**



The woodlouse spider has large fangs that it uses to puncture the tough exoskeletons of woodlice



## What's the green sheen on bacon?

ROB BAYNES, LUTTERWORTH



It is formed by a chemical reaction between the sodium nitrite that is used to cure the bacon, and myoglobin, which is found in muscle tissue. This reaction was identified in 2012 but we still don't know whether the green chemical is harmful or not in the long term. The nitrites in processed meat are already linked to heart disease, though. **LV**



## Why do women feel the cold more than men?

ALAN HEALY, FRANCE

Partly this is because, for a given bodyweight, women tend to have less muscle tissue to generate heat. But the hormone oestrogen also has a big impact because it has the side effect of thickening the blood slightly. This

reduces blood flow to the tiny capillaries supplying the extremities. A 1998 study at the University of Utah found that this can mean women have hands, feet and ears that are 3°C colder than a man's. **LV**



## What are the chances of being hit by falling space debris?

THERESA BROOKS, CUMBRIA

There are over 1,400 satellites orbiting over us, plus thousands of pieces of space junk that might survive entry through the Earth's atmosphere. But the chances of being hit are extremely low. Most of the Earth is covered by sea, and the majority of land is uninhabited. All told, the European Space Agency puts the lifetime risk of being hit at less than a billion to one. **RM**

### IN NUMBERS

# 39

The percentage of household food waste that's made up of fruit and vegetables.

# 830

The number of women who die every day due to complications during childbirth.

# 8

The amount of time, in minutes, that British tennis champion Andy Murray spends in an ice bath after a match.



# Can we unlearn things?

MIA LEE, GLASGOW

To some extent, yes. Psychologists have tested this in various ways, including asking people to spend time learning pairs of words, and then asking them to deliberately forget some of them. Future memory for the deliberately forgotten words tends to be poorer. More recently, researchers have extended this concept to show that people can unlearn behavioural habits acquired in the lab (such as particular finger movements paired with specific words), and they've found that after a period of deliberately not thinking about a particular autobiographical episode from their lives, people show a loss of memory details for that episode. **aj**



Somehow, we never seem to unlearn the lyrics to the Go Compare advert...

## THE THOUGHT EXPERIMENT

## IF I WENT UP IN A BALLOON UNPROTECTED, WHAT WOULD KILL ME FIRST?



### 1. HYPOTHERMIA

Air temperature drops by 5°C for each 1km you rise. By the edge of the stratosphere (around 15km), it's below -50°C and the wind blows at over 100km/h. Exposed skin will suffer frostbite in less than five minutes and hypothermia will soon follow. The temperature starts rising again after 20km, but not quickly enough to save you.



### 2. ASPHYXIATION

Well before you reach that altitude, though, you will have blacked out from oxygen deprivation. Passenger aircraft automatically release oxygen masks if the plane depressurises above 4.5km. If your balloon doesn't have its own air supply, you will be unconscious by the time you reach 10km, and dead a few minutes after that.



### 3. DEPRESSURISATION

Even with an oxygen mask, you won't survive past 18km. This is the Armstrong Limit, and is the altitude where water boils at body temperature. Above this point, the moisture in the lining of your lungs evaporates and they lose their ability to absorb oxygen. The only way to prevent this is to breathe pressurised oxygen in a sealed flight suit.

## Why do we get navel fluff?

GEOFF GRAVES, MANCHESTER



Navel lint, or belly button fluff, is mostly made from your underwear. The majority of clothing fibres just contribute to house dust, but underwear fibres get caught by the hairs below your belly button, which points upward and towards your mid-line. As your underclothes rub against your skin, the fluff ratchets its way up to your navel. Men get more body hair. **LV**



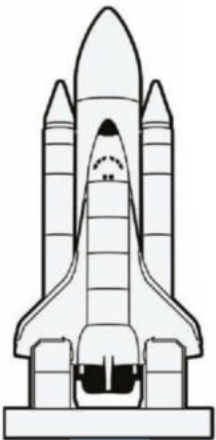
## Does the average person really exist?

GRACE SMITH, LONDON

In the UK, the average man and woman are 178cm and 164cm tall respectively, and earn around £34,000 and £25,000 – and we might even know people who fit these two characteristics. But the search rapidly gets harder as we add more 'typical' characteristics, those who perhaps also drink the average amount per week, spend the average amount on food and so on. You'd need hundreds of people to find at least one matching all these characteristics, and ever more as you try to pin down the ultimate 'average person', who is so unlikely they probably don't exist. This is a major challenge to 'personalised' medicine, as many drugs have been shown to work on average, but then fail with many patients – none of whom is ever just average. **RM**

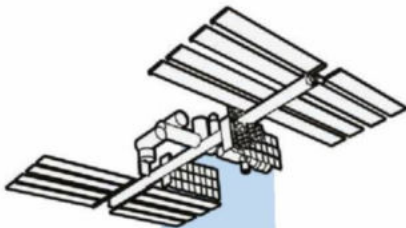
### TOP 10

## MOST EXPENSIVE SPACE MISSIONS\*



### 1. Space Shuttle Program

Date: 1981–2011  
Cost: \$199bn



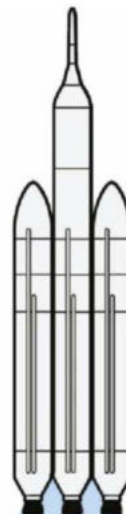
### 2. International Space Station

Date: 1998–2020  
Cost: \$160bn (estimated)



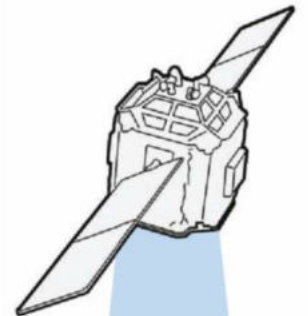
### 3. Apollo Space Program

Date: 1961–1972  
Cost: \$109bn



### 4. SLS and Orion (NASA's replacement manned rocket and capsule)

Date: 2014–2018  
Cost: \$23bn (estimated)



### 5. Global Positioning System (GPS)

Date: 1978–present  
Cost: \$12bn

\*(Figures in billions of US dollars, adjusted for inflation)



## Does warm milk help you sleep?

THOMAS MITCHELL, CHELMSFORD



Warm milk may be soothing, but the jury is out on its soporific qualities. Milk contains a protein called alpha-lactalbumin, a source of the amino acid tryptophan. This forms serotonin, a neurotransmitter that helps to regulate mood and sleep. Consuming alpha-lactalbumin increases blood levels of tryptophan. However, research shows that a large dose is

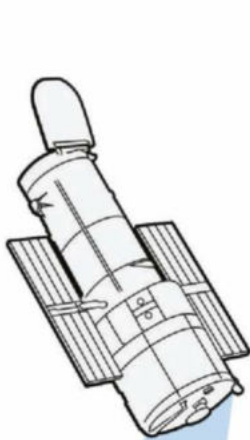
required to give enough tryptophan for the desired effect. Milk also contains a bioactive peptide, casein hydrolysate, which is thought to have anti-stress properties, while magnesium could help with restless legs. A Dutch trial on 15 women with insomnia suggests that milk may improve sleep, especially when enriched with magnesium and the protein casein hydrolysate. **ED**



## Is it possible for your head to weigh too much?

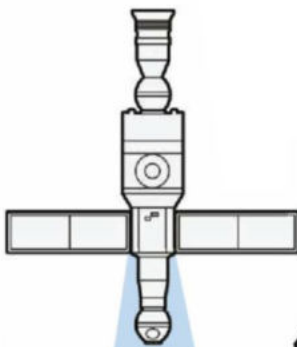
LORI SAUTTER, USA

An adult head weighs between 5kg and 6.3kg. Your neck muscles could cope with more weight, but an abnormally large head is usually a sign that something else is wrong. Proteus syndrome, for example, is caused by an extremely rare mutation in the AKT1 gene, right at the start of embryonic development. This causes excessive bone and tissue growth, and depending where the affected cells end up, it can cause a wildly oversized head. **LV**



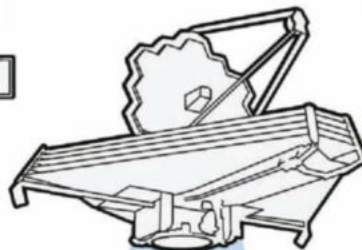
### 6. Hubble Space Telescope

Date: 1990-present  
Cost: \$10bn



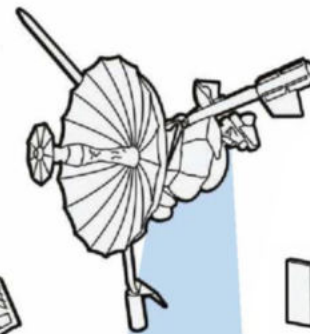
### 7. Salyut 6

Date: 1977-1982  
Cost: \$9bn



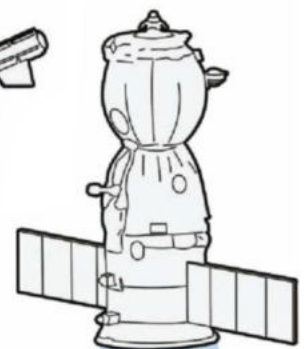
### 8. James Webb Space Telescope

Date: Scheduled for 2018  
Cost: \$8.8bn (estimated)



### 9. Galileo (Europe's GPS)

Date: 2016  
Cost: \$6.3bn (estimated)



### 10. GLONASS (Russia's GPS)

Date: 1982-present  
Cost: \$4.7bn



Strange but true:  
cabbage leaves may  
help ease pain caused  
by mastitis

## Do cabbage leaves cure mastitis?

KAREN DENNIS, BRIGHTON

Mastitis, which causes breast tissue to become sore and inflamed, is most common in breastfeeding women. Despite patchy scientific evidence, mums all over the world swear that slipping cabbage leaves in the bra can work wonders. Furthermore, a recent study at a Cairo maternity hospital suggests that cold leaves reduce the engorgement that can lead to mastitis. Most advocates agree that the leaves need to be chilled, and some recommend cooking them first to release chemicals from the cells. So how do the leaves work? The cold helps, especially when alternated with a warm compress. But the key may lie in the fact that cabbages contain glucosinolates. Enzyme action converts these to pungent isothiocyanates, collectively referred to as mustard oil. And mustard oil has long been used as a home remedy for swelling. **ED**

### HEAD TO HEAD



## TURBOCHARGER

## SUPERCHARGER

150,000-  
280,000rpm

### COMPRESSOR SPEED

30,000rpm

70kPa

### BOOST PRESSURE

100kPa

60-75kW

### EXTRA POWER

40-130kW

106dB

### NOISE

116dB

£2,400

### COST

£3,000

Both increase engine power by compressing the intake air. This allows more fuel to be burned for each piston stroke. A supercharger uses a turbine driven by the engine, which uses

some engine power. Turbos are powered by the otherwise wasted exhaust gas pressure. They are more efficient but more complex, and are less responsive when you accelerate.



## Could a computer conduct an orchestra?

DAVID HAYES, REDRUTH

At least two already have. In March 2004, Sony's QRIO robot – a 58cm high humanoid bot that's also rather good at dancing – conducted the Tokyo Philharmonic Orchestra for a performance of Beethoven's Fifth Symphony. A few years later in 2008, Honda's Asimo conducted the Detroit Symphony Orchestra performing *Impossible Dream*. The results sounded rather good, which is more than can be said for Russian media artist Dmitry Morozov's work in 2015. In his artwork called *Nayral-Ro*, a human was able to conduct a bizarre robot orchestra of buzzing and bleeping devices, producing 'music' more reminiscent of a fax machine than a symphony. **PB**





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Honda's Asimo robot proved surprisingly adept at conducting an orchestra

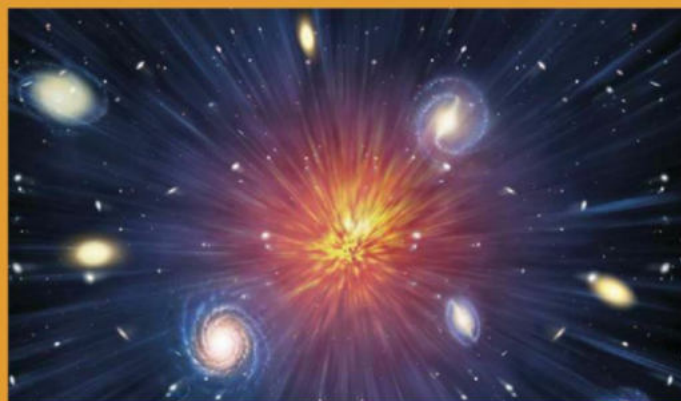
PHOTOS: GETTY X4, SCIENCE PHOTO LIBRARY



## Are coywolves a new species?

LIZ RUSSELL, BROMLEY

Creating a new species is not as easy as it may appear on the surface. DNA testing tells us that the fashionably named 'coywolf' is in fact just a variation of a coyote living across eastern Canada and the US. These adaptive 'super predators' carry genes from the coyote, wolf and domestic dog that differ in ratio depending on geographic location. Throughout the last century, deforestation and farming activities caused interbreeding between these biologically similar animals resulting in the evolution of *Canis latrans* var. – a successful canine mix, but not a genetically distinct species. Yet! **cc**



## Is everything in the Universe expanding at the same rate?

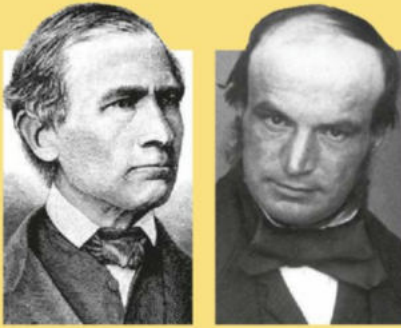
BEN SPINDLER, STAFFORDSHIRE

The Universe is expanding at a rate of around 75,000km/h for every million light-years distance, on average. That might sound a lot, but it's only apparent over galactic distances, where gravity no longer dominates. Everyday objects don't take part in the cosmic expansion; if they did, there'd be no cosmic expansion, as our standard 'yardsticks' would also expand, hiding any change. **RM**



## WHO REALLY DISCOVERED?

## NEPTUNE

JOHANN  
GALLEJOHN COUCH  
ADAMS

On the night of 23 September 1846, the German astronomer Johann Galle noticed an object in the constellation Aquarius which didn't appear on the latest star maps. Its disc-like appearance suggested it was a new planet – a conclusion confirmed the following night by its movement relative to the distant stars.

Galle had discovered Neptune, but it was no accident. He had been asked to examine that patch of the night sky by Urbain Le Verrier, a brilliant French theoretician who had been examining strange effects in the orbit of Uranus, and concluded it was being affected by an unseen planet. But just as Galle and Le Verrier were being hailed for their discovery, British astronomers claimed a young Cambridge mathematician, John Couch Adams, had made similar calculations, and that a British astronomer had subsequently seen Neptune three times – but failed to recognise it. This attempt to grab some of the glory sparked an international row – which intensified when American astronomers argued that the predictions were faulty, and the discovery merely a “happy accident”. Recent research has led historians to dismiss the British claim. But it's now known Galle wasn't the first to see Neptune: studies of Galileo's notebooks show he unwittingly saw it as early as 1612. **RM**



Iris recognition is just one of many possible forms of biometric identification

## What is the most accurate type of biometric identification?

CHARLIE TAUNTON, LEICESTER

Biometric technologies are designed to recognise you, acting like a password to give you access to a computer system or pass through a security system. Some listen to your voice or examine your signature, some read fingerprints or measure faces, some examine retinas or study your brainwaves, some even measure the geometry of your hands or the shape of your ears. DNA identification may seem very accurate but only tiny

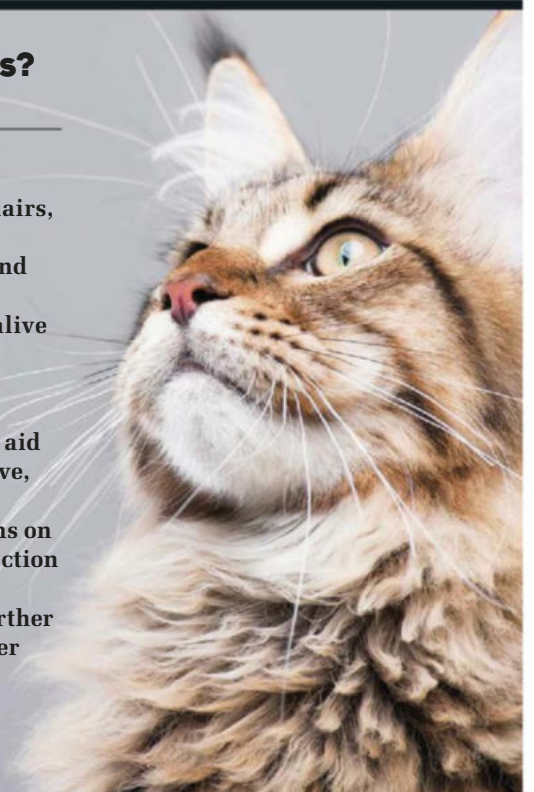
parts of your DNA are examined during a DNA profiling test, and it is easy for samples to become contaminated with other DNA, so it might only be accurate to one in a few thousand. The most accurate approach will always be to use several methods in combination, because the chances of you having the same shaped face, the same fingerprint and the same retina as another person are infinitesimally small. **PB**

## Why do cats have whiskers?

ANNA DAVIES, LIVERPOOL

A cat's characteristic 'moustache' of vibrissae, made up of 24 or so mobile hairs, is accompanied by other less apparent whiskers above the eyes, on the chin and the back of the front paws (the carpal whiskers). These thickened hairs are alive with deep-rooted nerves that help our feline friends literally feel their way through a hunt, especially in the dark. Facial whiskers align to body width to aid with judging distance while on the move, and precision killing is enabled by 'proprioceptors', special sensory organs on the tips that monitor the distance, direction and even texture of prey.

Whiskers also monitor airflow to further coordinate their locomotion. No wonder your cat is such a graceful beast! **cc**



PHOTOS: ALAMY, GETTY X4, SCIENCE PHOTO LIBRARY





## WHAT IS THIS?

### **Blooming lovely**

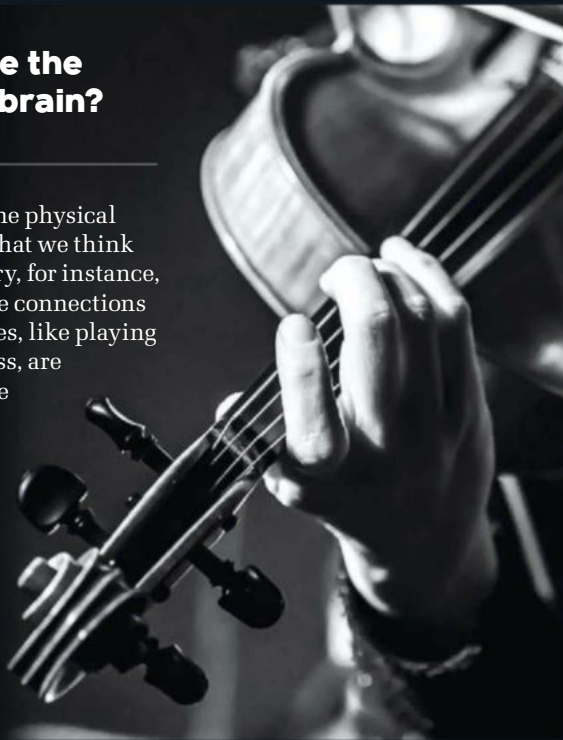
This picture shows a bloom of algae that occurred in Utah Lake, Utah last summer. The lake covers an area of 385km<sup>2</sup>, and nearly all of it was covered by the bloom. The proliferation of algae was probably caused by warm weather, low water levels and run-off of pollutants from the neighbouring land. Some samples taken from the lake and surrounding waterways contained high levels of cyanobacteria, also known as blue-green algae, which can be toxic.



## Does experience change the actual structure of the brain?

RICHARD NEVIS, CARDIFF

Almost everything we do changes the physical structure of our brains, including what we think about. Each time you recall a memory, for instance, you are effectively strengthening the connections between brain cells. Skilled activities, like playing musical instruments or playing chess, are associated with larger changes to the size of specific brain regions. For example, violinists have more brain tissue dedicated to representing the fingers of their left hand, and expert chess players have reduced grey matter – a possible sign of neural efficiency – in an area associated with representing how objects are related to each other. **Q**



## Which life form has the biggest genome?

CARL ROTHER, EXETER

There is still no comprehensive list of genome sequences of all life forms. But from what is available, it looks like the Japanese canopy plant is currently the biggest, with 50 times more DNA than the human genome. Of the animals, the marbled lungfish's genome (*Protopterus aethiopicus*) weighs in at 44 times ours.

But while size matters for biodiversity studies and understanding the evolution of such large genomes, bigger doesn't necessarily mean more complex. A larger genome size may simply be indicative of repetitive DNA, rather than a greater number of genes that actually contribute to the organisms' code. **AP**

### WHAT CONNECTS...

#### ...GOLD AND EARTHQUAKES?



# 1.

Almost all the gold present in Earth's crust today was delivered by asteroid impacts four billion years ago. Since then, it has been buried under lava flows and other rock strata.

# 2.

Gold is one of the least reactive elements, but it will dissolve very slightly in water. There are about 20g of gold dissolved in every cubic kilometre of seawater.



# 3.

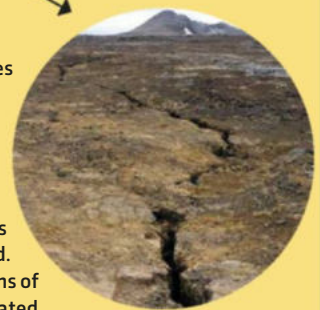
This dilute gold solution seeps into many rock formations as groundwater.



However the concentration, just 10 parts per quadrillion, is far too low to make mining economical.

# 4.

Earthquakes force open cracks and the sudden pressure drop precipitates out the gold. Over millions of years, repeated earthquakes build up veins. Eighty per cent of the world's gold deposits were formed this way.

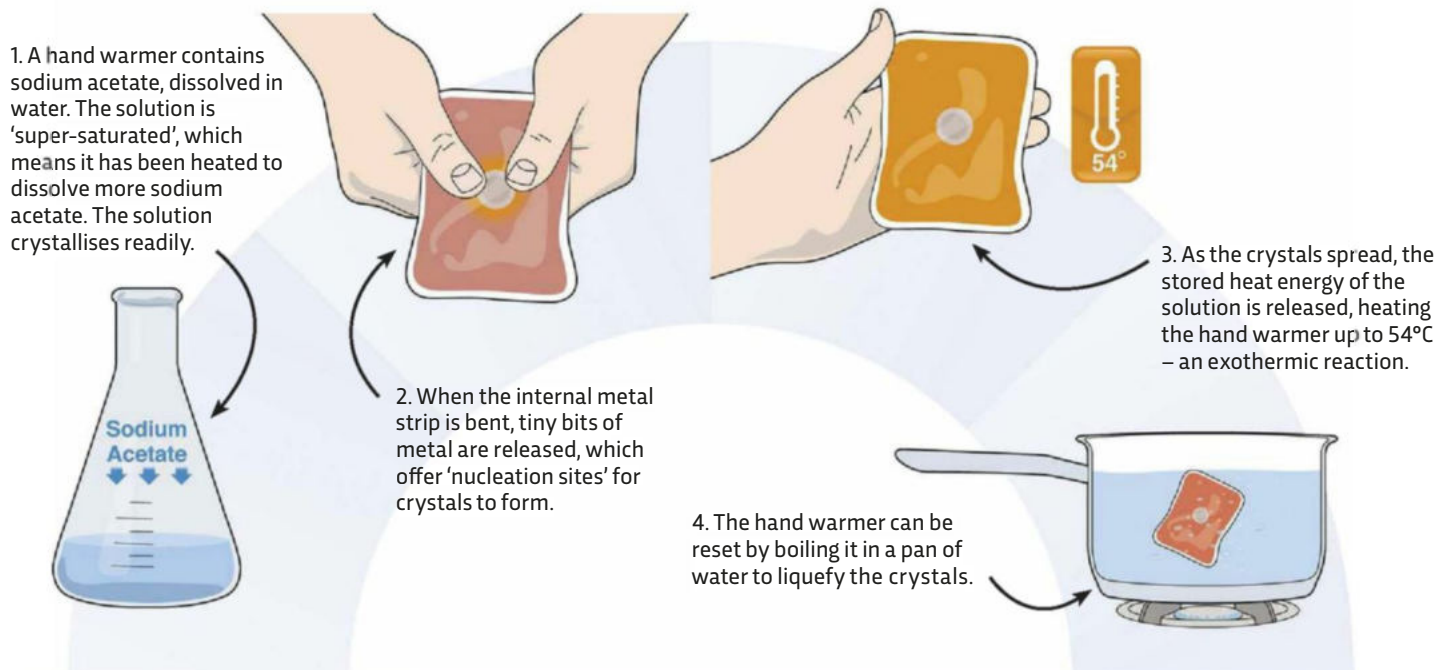




## HOW IT WORKS

# RE-USABLE HAND WARMERS

On cold days, a hand warmer can offer comfort to the chilly-fingered. Yet the science behind them is surprisingly straightforward...



## QUESTION OF THE MONTH

### What causes middle age spread?

EDWARD SEYMOUR, HOVE

Babies are vulnerable to the cold, because they are small and can't move themselves out of draughts or the wet. Evolution has compensated by giving them brown adipose tissue, or BAT (it's often called 'brown fat' but it's actually more like muscle). BAT generates heat by metabolising fat in a deliberately inefficient way. About 5 per cent of the bodyweight of a newborn baby is BAT, but as you grow older you don't need this wasteful metabolic afterburner. From your teens onward the BAT gradually changes into ordinary fat tissue. In our twenties and thirties, we generally compensate with a more active lifestyle, and the strain of raising children. But by the time we reach our forties, that has begun to taper off. We suddenly don't need to book a babysitter just to go out for the evening. Restaurant food, alcohol and disturbed sleep patterns can all contribute to weight gain. Even more importantly, we don't have the same capacity or enthusiasm for exercise as we once did. The less muscle tissue we have, the fewer calories we need to support it, and yet somehow, no one tells our stomachs. One day we cross an invisible threshold where 'calories in' are greater than 'calories out' and the weight begins to pile on. **LV**

### WINNER!

Edward Seymour wins a ProofCam Watchdog Full HD dashcam. It comes with built-in Wi-Fi, so you can download recorded videos direct to your smartphone (£60, [proofcam.com](http://proofcam.com)).

## NEXT ISSUE:

What is dark energy?

Is there acid snow?

Do dogs have visual dreams?

Email your questions to [questions@sciencefocus.com](mailto:questions@sciencefocus.com) or submit online at [sciencefocus.com/qanda](http://sciencefocus.com/qanda)

# OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

FEBRUARY 2017

EDITED BY JAMES LLOYD



PHOTO: GETTY





01

**THE LAKE DISTRICT: A RESTLESS YEAR**  
BBC TWO, FEBRUARY.

## REDISCOVER THE LAKE DISTRICT

With over 17 million visitors a year, the Lake District National Park is one of the UK's most popular holiday destinations. But away from the honeypot towns and bustling tea rooms, the area remains a place of rugged, unspoilt beauty.

This new film from the BBC's Natural History Unit follows a year in the life of the Lake District, from the rain and sunlight of spring and summer to the icy storms and long nights of autumn and winter.

Filmed using a range of techniques, including time-lapse, super slow-mo and macro photography, we see baby slugs hatching in dry stone walls, red squirrels burying nuts, hills erupting in bluebells, and intrepid climbers rescuing sheep trapped on rocky ledges.





## 02

## GET OUR TEETH INTO CANNIBALISM

It's one of the last great taboos and a mainstay of horror films. But, as zoologist BILL SCHUTT reveals in his new book, cannibalism is an oft-misunderstood topic...

### **Why did you decide to write a book about cannibalism?**

Most of the books written about cannibalism in the past have either been really sensationalist, or aimed at academics. I wanted to write a book that's somewhere in the middle, a book that's entertaining and informative but also shows that cannibalism doesn't always have to be grotesque. There are fascinating and even beautiful aspects to this phenomenon.

### **Where do we see cannibalism in the natural world?**

Cannibalism is natural behaviour across the entire animal kingdom. It's extremely common in insects and other invertebrates, and in vertebrates like fish and amphibians. It also happens, though far less commonly, in birds and mammals.

The most well known example is probably sexual cannibalism in spiders, where the females of some species consume the males after mating. From an evolutionary perspective this makes sense – the male is giving the impregnated female a good meal, increasing the likelihood that she will survive and propagate his genes.

### **What other animal species are known to practice cannibalism?**

Male lions have been known to eat their rivals' young, because this

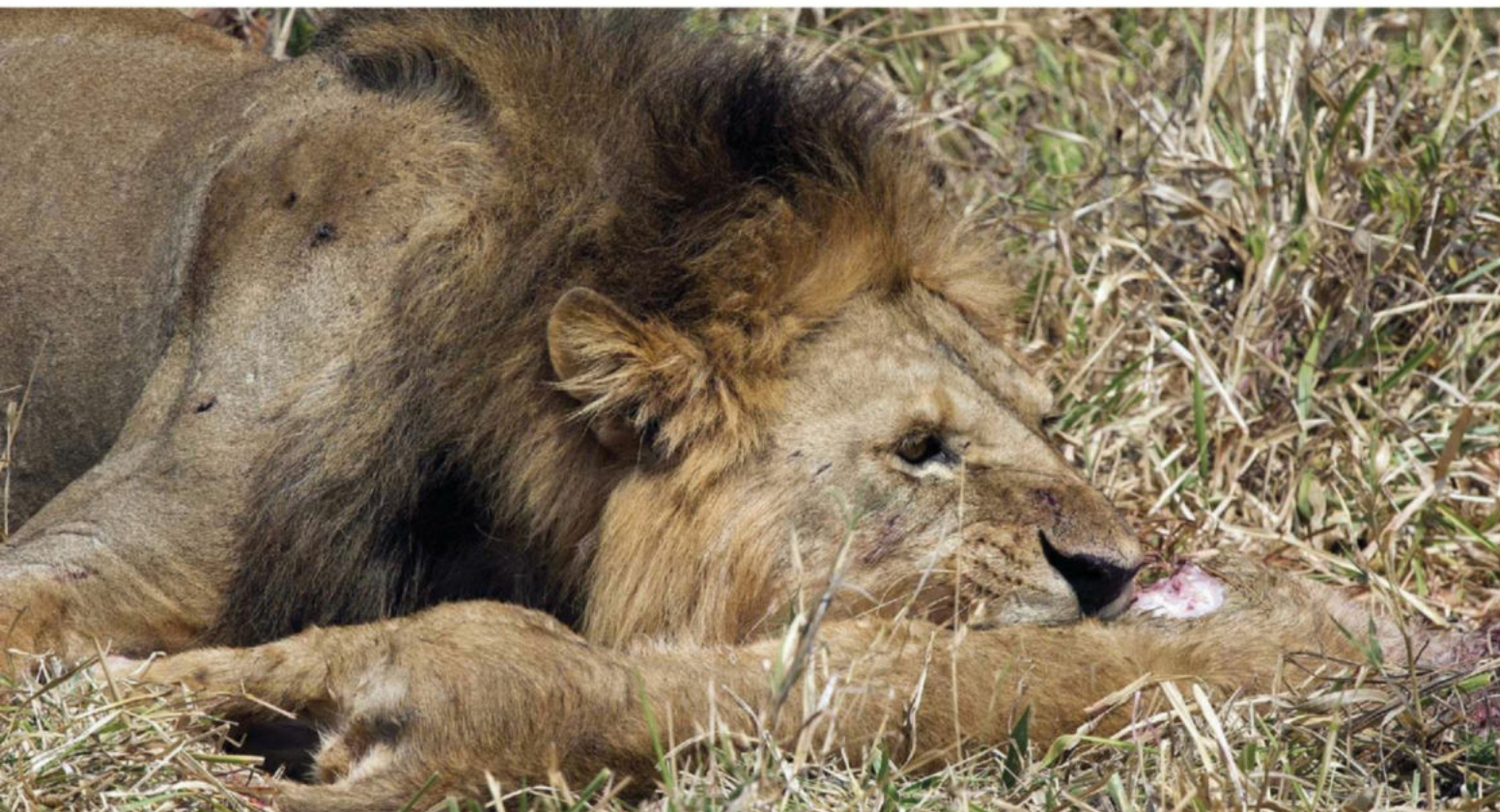
brings the lioness back into heat much quicker, so that the male can father his own cubs. It can also be a form of parental care – infant caecilians, a group of limbless amphibians, feed on their mother's skin – and many bird chicks will eat their weaker siblings.

Then there's indiscriminate cannibalism amongst fish. Some fish lay millions of eggs, and they won't necessarily recognise them all as individuals of their own species. Cannibalism is just a way to take advantage of this abundant source of nutrition.

### **Why do humans sometimes eat each other?**

We hear mostly about criminal cannibalism, but I didn't want to focus on this aspect or glorify it in any way. Instead, I looked at the instances where cannibalism makes more sense. Before it became a Western taboo, it featured in funerary practices in communities around the world – the Fore people in Papua New Guinea would often eat their deceased as an expression of love and grief. Cannibalism has also served as a food source during sieges and times of famine, and amongst survivors of disasters and strandings. It also used to be widespread in medicine – assorted body parts and blood were consumed for hundreds of years as cures.





Male lions sometimes eat the young of their rivals, in order to bring the mother back into heat

#### Is it still performed anywhere today?

If it is, then it's done in secret among isolated communities. There are, however, people who still eat their own placentas. This has recently become more popular in the United States: some mothers claim that it helps them feel better by rebalancing their hormone levels post-birth. There's no scientific evidence for this, so it's probably a placebo effect, but there probably isn't any harm in it either.

I even tried it for myself! I was invited to Texas to sample the fresh placenta of a woman who'd just had her 10th child. Her husband cooked it up and it was delicious. I'm not going to reveal what it tasted like, but I will say that it went well with red wine!

#### Why do you think we're so disgusted at the thought of cannibalism?

A lot of it is cultural – there are negative associations in film and literature going all the way from Ancient Greek mythology, through to Shakespeare, the Brothers Grimm and Hannibal Lecter. But there are also biological reasons. You wouldn't want to eat your

## ***"Another major drawback to cannibalism is that it involves ingesting parasites and diseases"***

family because you'd be taking your own genes out of the population too, reducing your future chance of evolutionary success (a concept known as 'inclusive fitness').

Another major drawback to cannibalism is that it involves ingesting parasites and diseases that have already evolved to defeat our immune systems, so it's not generally a healthy thing to do.

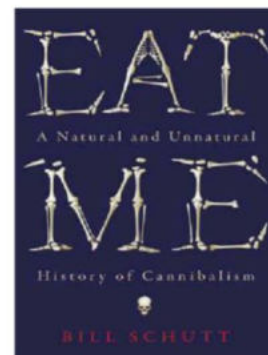
#### Could cannibalism ever make a comeback?

I think it could. In nature, overpopulation is a primary cause of cannibalism. In humans, combine this with a lack of alternative nutrition – say during an agricultural crisis – and I can see it happening. I'd be mortified,

but I wouldn't be surprised – if you put enough environmental stresses on a group of people, they will turn to cannibalism in order to survive.

#### **EAT ME: A NATURAL AND UNNATURAL HISTORY OF CANNIBALISM BY BILL SCHUTT**

OUT 2 FEBRUARY (£14.99, PROFILE BOOKS/ WELLCOME COLLECTION).





## 03 SAY HELLO TO ERIC

**ROBOTS**  
LONDON SCIENCE  
MUSEUM,  
8 FEB – 3 SEPT 2017.  
SCIENCEMUSEUM.ORG.  
UK/ROBOTS

Built in 1928, Eric was the UK's first robot – a talking, moving automaton that was created by Captain Richards and AH Reffell less than a decade after the word robot was first used. But after wowing crowds in Europe and the US, he mysteriously disappeared.

Now, with the help of 861 backers on Kickstarter, London's Science Museum has brought Eric back to life, recreating him for a blockbuster exhibition opening this month. *Robots* explores our 500-year quest to reimagine ourselves in mechanical form, from a 16th-Century articulated iron manikin to the newly-restored Inkha, a robot receptionist who greeted visitors to King's College London between 2002 and 2014. There will be over 100 robots on display, prompting visitors to think about the way our ever-more-human contraptions have been shaped by religious belief, the Industrial Revolution, popular culture, and our visions of the future.

Head to the Science Museum website (see left) for full details of the exhibition and the accompanying programme of events, which include film screenings, panel discussions, a comedy quiz show and a robot-themed sleepover for grown-ups.



## 04

**BRIGHTON SCIENCE FESTIVAL**  
11 – 19 FEB 2017.  
BRIGHTONSCIENCE.COM

## VISIT THE SEASIDE

Oh we do like to be beside the seaside, especially when there's science involved too. Brighton Science Festival returns this February half-term for a week of fun-filled shows and activities on the East Sussex coast.

Highlights include Bright Sparks – a family-friendly weekend that's designed to get parents and children doing science together – and a Festival of the Spoken Nerd event that sees the comedy trio teaming up with 'anarchist cook' George Egg to create the world's most scientifically accurate dessert.

Other familiar faces at the festival include the BBC's Marty Jopson, who's exploring the science of everyday life, and Prof Richard Wiseman, who will reveal the psychology behind magic tricks and illusions. Prepare to be bamboozled.



PHOTOS: THE BOARD OF TRUSTEES OF THE SCIENCE MUSEUM, FRAN MOORE



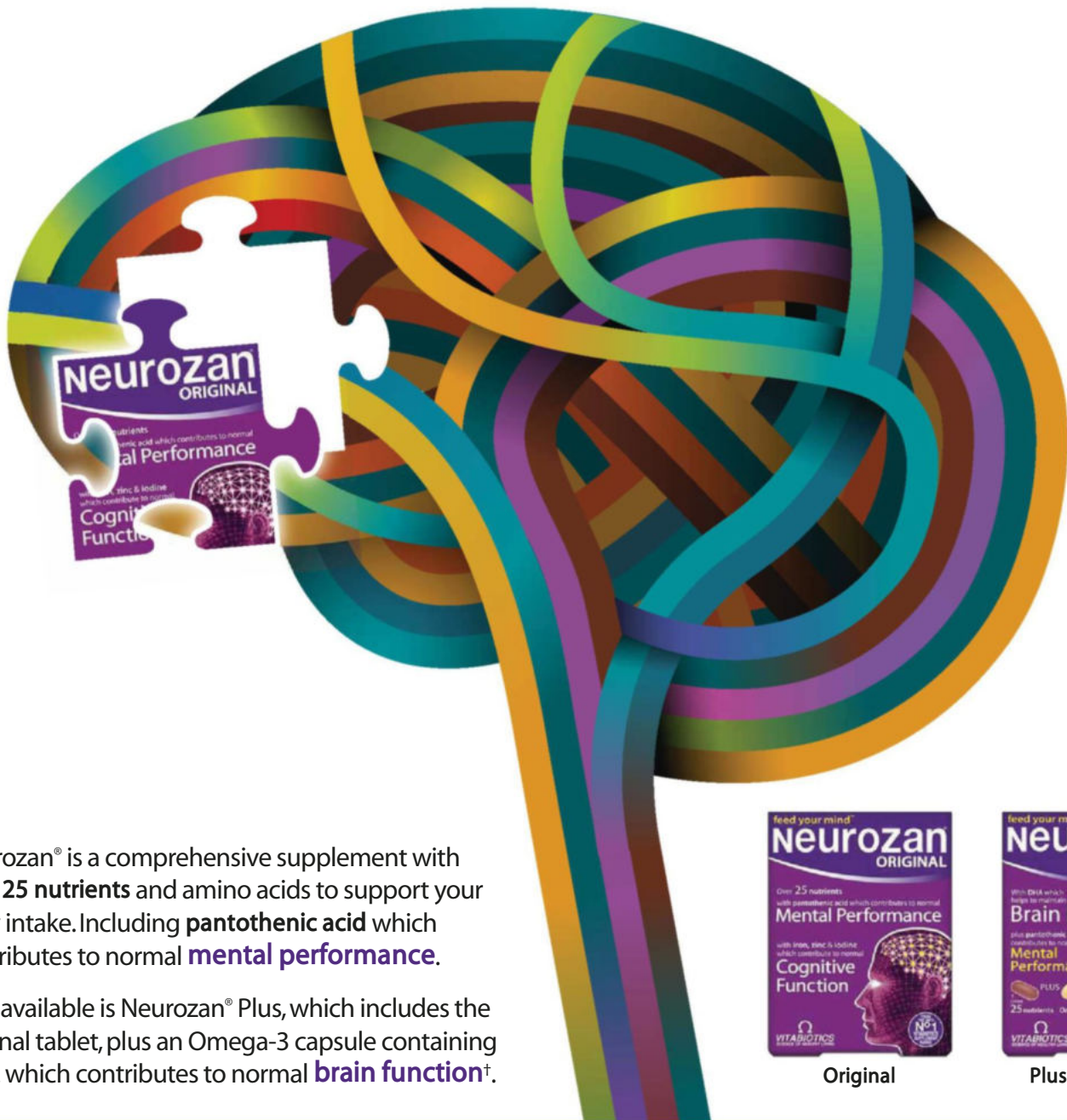


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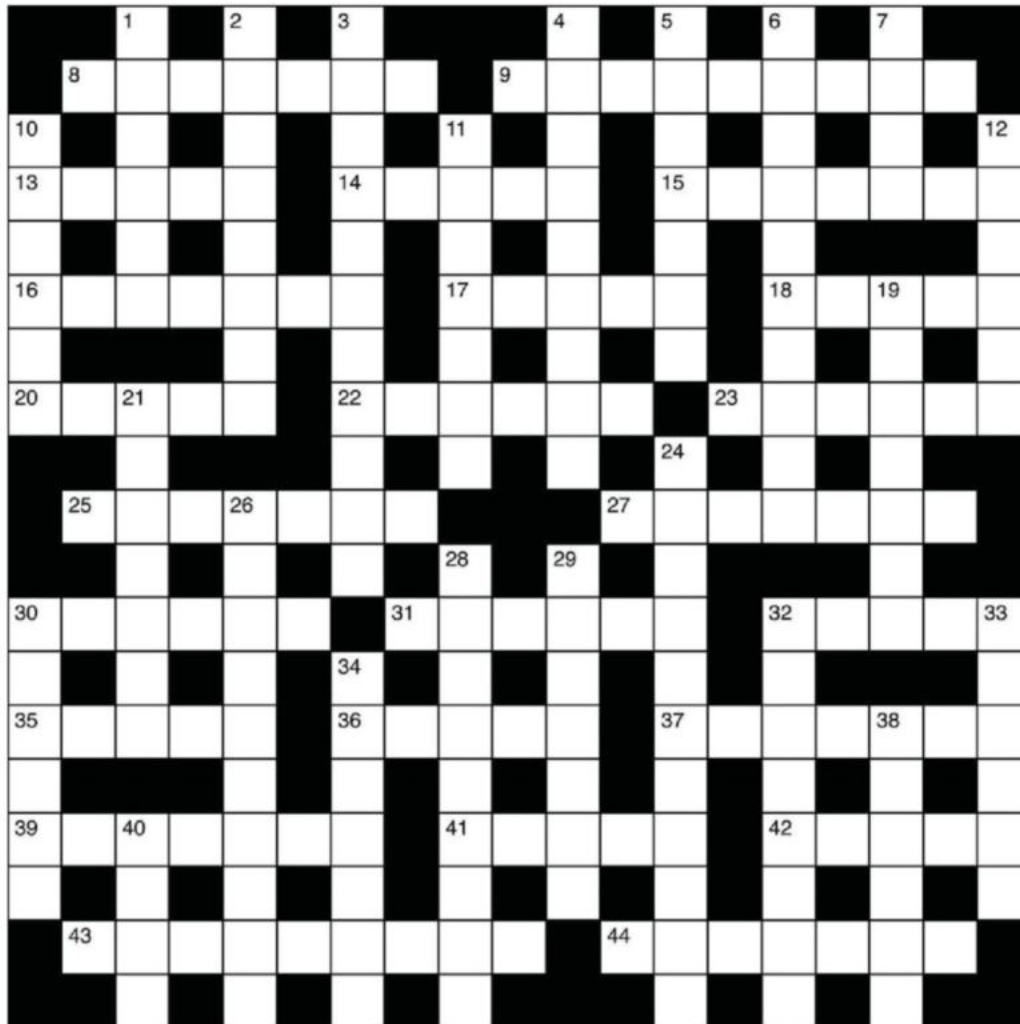
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# SCIENCE CROSSWORD

## GIVE YOUR BRAIN A WORKOUT



### ACROSS

- 8 God has hesitation with one thing that's radioactive (7)  
 9 Changes are remote to density gauge (9)  
 13 Waste doctor on old ship (5)  
 14 Time to hire a river (5)  
 15 Little bit of mercy (7)  
 16 Mathematics showed gale affected underwear (7)  
 17 Howls audibly for material (5)  
 18 Point a leg out to a bird (5)  
 20 Rejection of joint (5)  
 22 True puzzle about the first large reptile (6)  
 23 German riles disturbed youngster (6)  
 25 Champ used gold as a cold treatment (7)  
 27 Mineral may irk teen terribly (7)  
 30 Crazy artist takes turn on island (6)  
 31 Picture section on chart (6)  
 32 Fancy Nicholas captivating pessimist (5)  
 35 Almost hide rock fragments (5)  
 36 Clip about union added weight in Asia (5)  
 37 Rush about to get old doctor into shape (7)  
 39 I am joining favourite American incentive (7)  
 41 Clever enough to be using the Internet (5)  
 42 Woman gets very warm in loincloth (5)  
 43 Cell distorted toe's image (9)  
 44 Expert in taking tellurium as a vital constituent (7)

### DOWN

- 1 Strap holds Republican crowd (6)  
 2 Weapon produces angry show of respect (8)  
 3 Removal of advance payment on spinal treatment (11)  
 4 Chamber revealing a bit of heart (9)  
 5 Some flowers have a nose (7)  
 6 Figure one cheddar was wrong (10)  
 7 Insect at last finds plant (4)  
 10 Notice neat arrangement, growing close to the next part (6)  
 11 Stranger berated about flower (7)  
 12 Three-bonded compound displayed inert energy (6)  
 19 Setting agent translation, say, to classical language (7)  
 21 Bishop takes steps to find inflatable part (7)  
 24 Moderate a true form of warmth (11)  
 26 Centre page is all about proportion (10)  
 28 Six send city SIOS, getting some resistance (9)  
 29 Morning gala mixed medium blend (7)  
 30 Sam is wrong about loud peaks (6)  
 32 Teach Rod about vertebrate (8)  
 33 Copper betting on identification of canine (6)  
 34 Poise conundrum, getting yours truly a bit of DNA (7)  
 38 Initially bartered one new coin, mechanically substituted (6)  
 40 Some flowers contain polonium, sulphur and yttrium (4)

### ANSWERS

For the answers, visit [bit.ly/BBCFocusCW](http://bit.ly/BBCFocusCW)  
 Please be aware the website address is case-sensitive.



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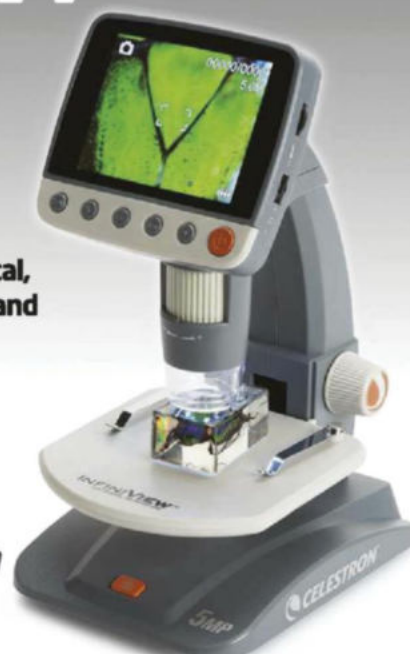
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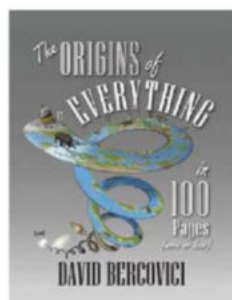
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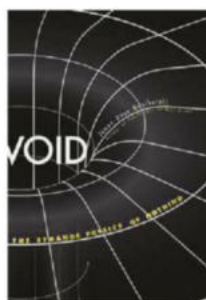




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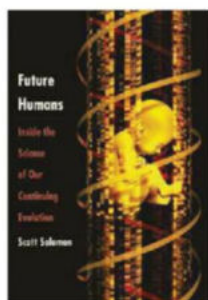
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**Shazia Fardous,  
Freelance Proofreader  
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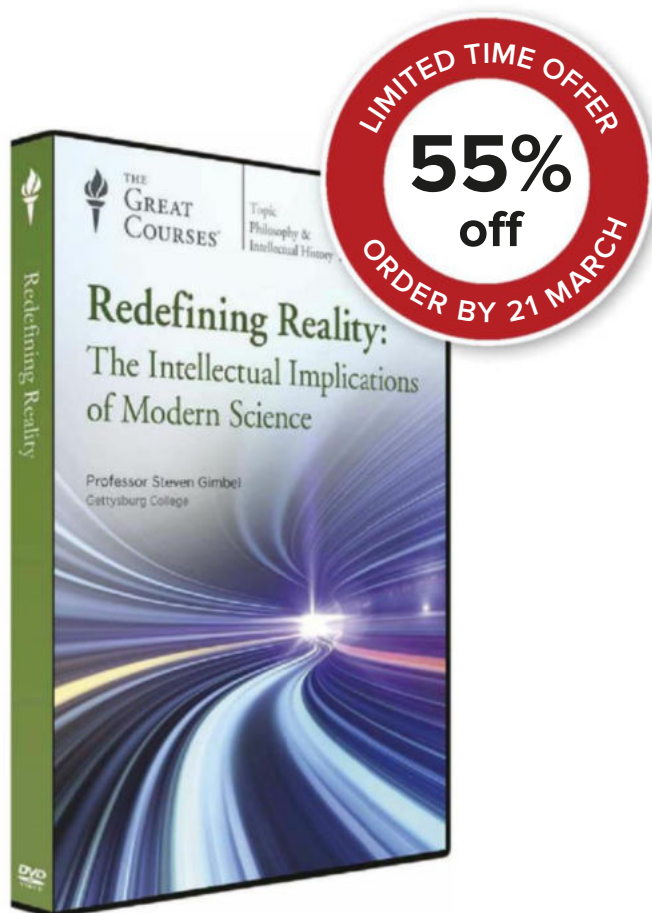


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